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Lean Six Sigma Yellow Belt

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Learning Objectives

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On completion of this training course, you will be able to:

- Describe how the concepts and tools of Lean and Six Sigma can be integrated to provide a focus on customer value streams and the reduction of non-value-added activities, defects and waste.
- Identify what constitutes a Lean Six Sigma (LSS) project and the factors that lead to effective improvements.
- Explain each phase of the LSS roadmap using the Define, Measure, Analyze, Improve and Control (DMAIC) methodology.
- Use LSS terms and concepts to communicate with others and provide support to Green Belts and Black Belts who are leading LSS improvement projects.
- Apply the most widely used tools for LSS projects, to include:

Define:	project charter for problem statement, value stream and workflow scopes, SIPOC, project metrics, team and resource definition
Measure:	process observation, process mapping, value stream mapping, data collection planning, and use of statistical metrics
Analyze:	run charts, Pareto charts, stratification analysis, root cause analysis (5 whys, affinity analysis, cause and effect diagrams)
Improve:	structured brainstorming, benchmarking, multi-voting, cause and effect matrix for solution impact, Lean solutions, stakeholder engagement and solution piloting
Control:	control plan, statistical monitoring via control charts, response plans, process capability

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Notes

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1 Basic Concepts of Lean

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The goal	• Provide the greatest value for customers using the fewest resources
The methods	• Principles and practices based on the Toyota Production System (TPS)
The barrier	• Culture can always defeat methodology
The path forward*	• Management must foster a culture of *continuous improvement* • Improve all processes, every day • Improvement cycles must be an integral part of the daily work of all employees

*See **Toyota Kata** (2010) by Mike Rother.

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Basic concepts of Lean (cont'd)

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1) Define *value* from the customer's point of view

2) Continually reduce or eliminate activities that do not add customer value

3) Focus on the *value stream*:

> The set and sequence of all activities required to provide a specified family of products or services to the customer

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Customer defines value

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Customer value adding (CVA)

- Activities that are required, from the customer's point of view, to produce/deliver the desired product/service
- What the customer is willing to pay for

Non value adding (NVA)

- There exists a feasible future state in which the desired product/service can be produced/delivered without these activities

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Common example of CVA and NVA

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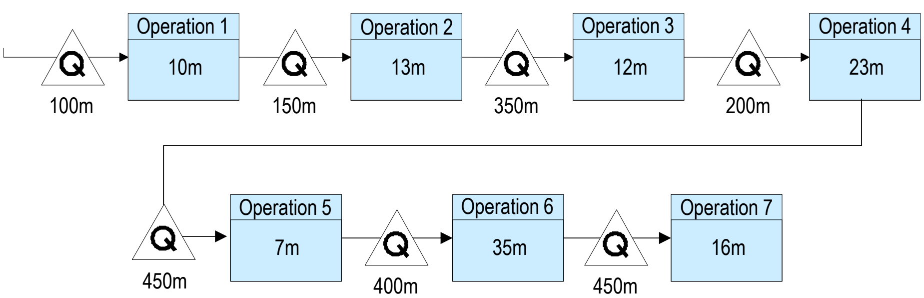
Typical current state value stream



Lead time = 2,216 mins
Touch time = 116 mins (5.3%)
Wait time = 2,100 mins (94.7%)

Q Queue (material or transactions waiting to be worked on) → 100% NVA

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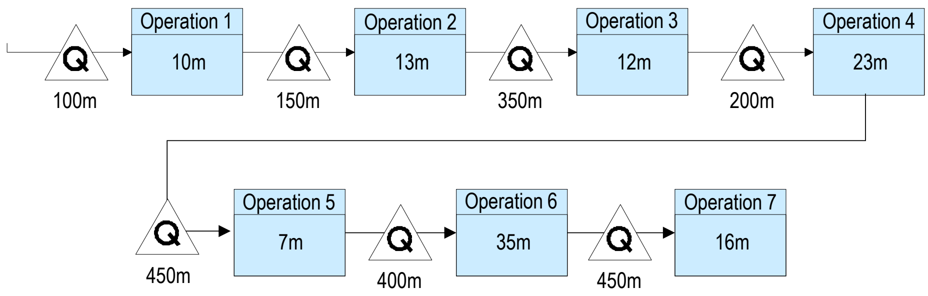
What is the priority: reducing CVA or reducing NVA?



	Current state	50% reduction in touch time	50% reduction in wait time
Touch time	116 m	58 m	116 m
Wait time	2,100 m	2,100 m	1,050 m
Lead time	2,216 m	2,158 m	1,166 m
	Reduction in lead time →	**2.6%**	**47.4%**

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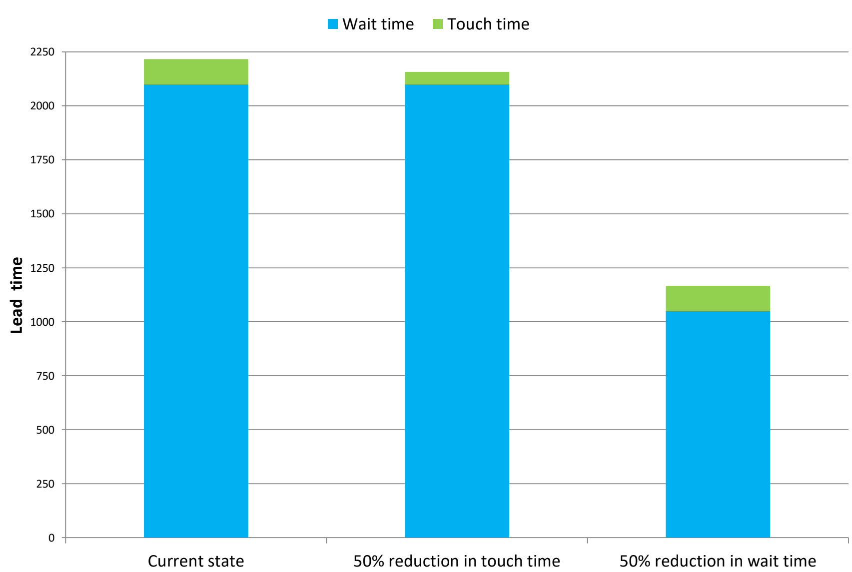
Reduce NVA, not CVA!



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Categories of NVA

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D	*Defects*: Failure to meet expected standards of quality or delivery
O	*Over production*: Making or doing more than is needed at the time
W	*Waiting*: People waiting to work, or things waiting to be worked on
N	*Not utilizing creativity*: Failure to integrate improvement cycles into the daily work of all employees
T	*Transportation*: People or things being moved from one place to another
I	*Inventory*: Supplies, WIP, or finished goods beyond what is needed
M	*Motion*: Excessive motion in the completion of work activities
E	*Extra processing*: Producing or delivering to a higher standard than is required

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Exercise 1: NVA identification

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Think of processes in your organization, and list examples of non-value adding (NVA) activities.
Try to identify more than one for each 'DOWNTIME' category.

D	*Defects*:
O	*Over production*:
W	*Waiting*:
N	*Not utilizing creativity*:
T	*Transportation*:
I	*Inventory*:
M	*Motion*:
E	*Extra processing*:

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2 Basic Concepts of Six Sigma

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Types of NVA associated with Six Sigma

Defects

Errors

Scrap

Rework

Late delivery

Returned goods

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Example of defects: not meeting product specifications

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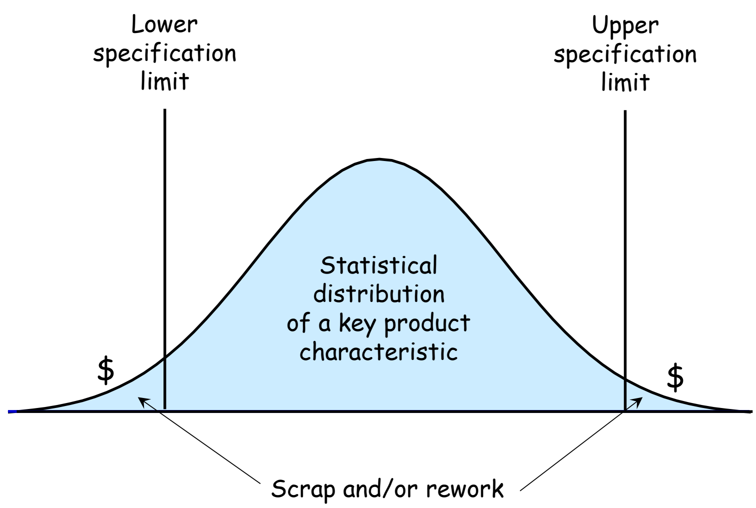

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Result of improvement project

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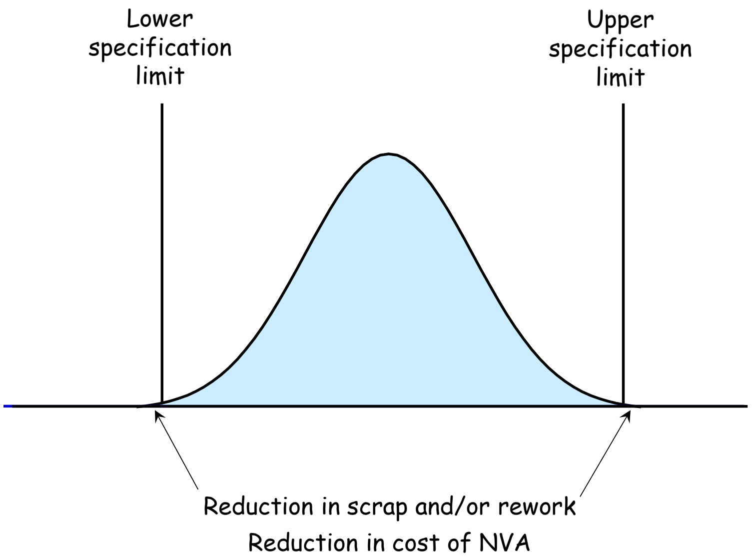

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Reasons to combine Lean and Six Sigma

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- They employ common strategies
- They focus on complementary problem areas
- They employ complementary methods

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Common strategies

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- Focus on customer satisfaction
- Focus on reducing waste and its cost
- Focus on processes and process improvement
- Improving processes via team projects
- Keep the improvement cycles going

Complementary problem focus and methods

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Lean	Six Sigma
Lead and Cycle time WIP Other visible waste	Defects “Invisible” waste
Defects caused by chaos and confusion	Defects caused by materials and equipment
Root causes easier to determine	Root causes harder to determine
Value stream mapping Geographic mapping	Basic process mapping Cross functional process mapping
“Tribal knowledge” “Wisdom of the organization”	Data analysis
Best practices from TPS provide a set of known solutions	Project roadmap provides a method for finding new solutions

3 The Lean Six Sigma Project Roadmap

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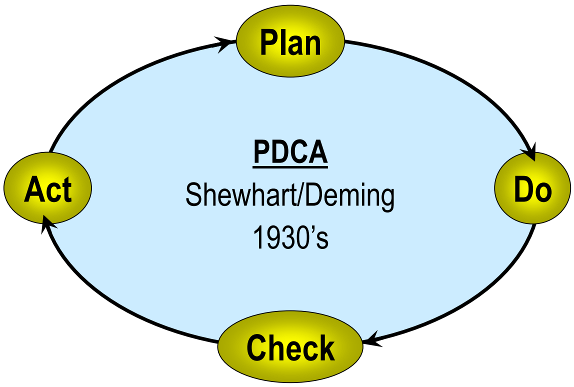
In the beginning there was...



One of the first applications of the scientific method to manufacturing and business processes

PDCA (cont'd)

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Plan
- ✓ Define the problem to be solved
- ✓ Collect and analyze data on the current process
- ✓ Brainstorm possible causes of the problem

Do
- ✓ Develop possible solutions
- ✓ Select the most likely solution
- ✓ Pilot the solution

Check
- ✓ Analyze the results to see if the problem has been solved

Act
- ✓ Implement the successfully piloted solution, or
- ✓ Start the cycle over again

Nowadays it's spelled D-M-A-I-C

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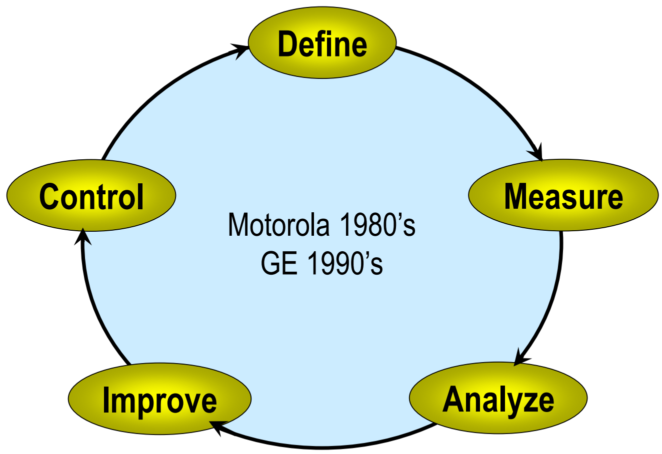
Most widely used process improvement methodology



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DMAIC has more "teeth" than PDCA

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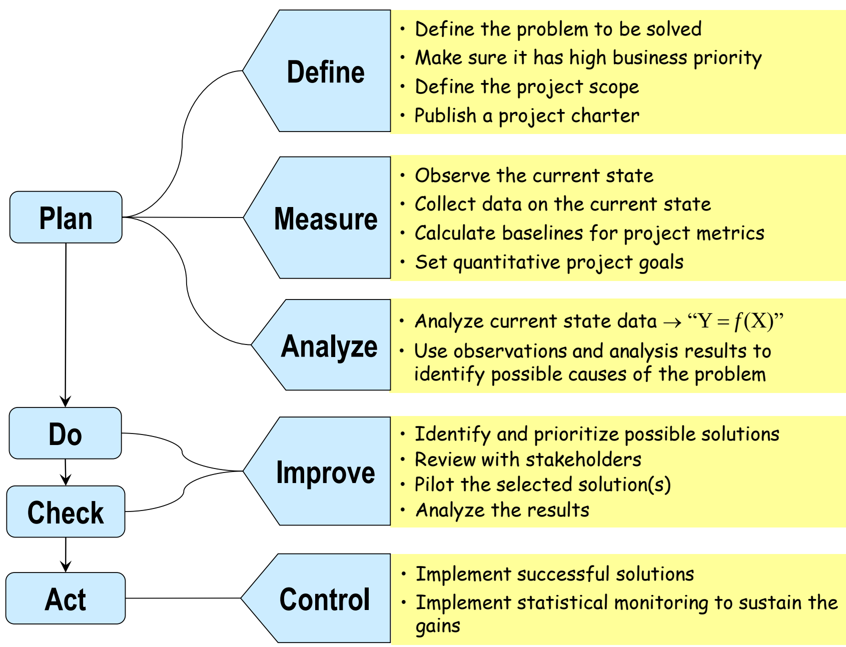

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Strengths of LSS projects

- ✓ Utilization of the DMAIC methodology
- ✓ Alignment with business priorities
- ✓ Clearly defined scope and boundaries
- ✓ Combined process observation and data analysis
- ✓ Problems solved by understanding them
- ✓ Conclusions supported by statistical standards of evidence
- ✓ Improvements verified quantitatively
- ✓ Statistical monitoring used to sustain gains

Characteristics of LSS projects

- We want to improve a process (the way we do something), or
- We want to improve a product (a way for customers to do something)
- The current process or product falls measurably short of what is needed or desired
- The cause of the problem is not known, or there is lack of consensus as to what it is
- Process observation and data collection/analysis are required
- Root cause analysis is required

LSS is *not* a set of solutions – it is a process (DMAIC) for *finding* solutions

Exercise 2: DMAIC mix and match

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Draw lines connecting the items on the right to the appropriate DMAIC phases on the left.

Define	Establish the current state
Measure	Develop the future state
Analyze	Sustain the gains
Improve	Develop the project charter
Control	Determine the root causes

Examples of LSS projects

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Reduce oxidation on titanium castings

Reduce injection molding setup time

Reduce repair shop turnaround time

Reduce injection molding defects

Reduce the cost of belt grinding

Reduce RFQ turnaround time

Reduce unplanned downtime

Other types of projects (non-LSS)

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- We know what needs to be done, and we want to do it
- It may be simple, quick, and cheap (a “just do it” project)
- It may be complex, time consuming, and/or expensive (a “project management” project)
- All of the above involve *implementing known solutions*
- These projects could be action items *resulting* from a LSS project, but they are not in themselves LSS projects

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Examples of non-LSS projects

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Automate a task that is currently done manually

Upgrade software to the latest revision

Revise outdated work instructions

Install a new piece of equipment

Obtain environmental permits

Replace outdated computers

Install a bar coding system

Build a plant in China

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Exercise 3: LSS vs other projects

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Classify these projects	LSS	Other
Implement the new ERP system we have decided to use		
Reduce errors in processing purchase requisitions		
Reduce wave solder defects		
Open a new branch office in the next town		
Reduce billing lead time		
Install a web-based ordering system		
Reduce non-manufacturing time from order to sell		
Reduce scrap in the coiling department		
Eliminate cracking of molded housings		
Reduce installation & warranty costs		
Increase the percentage of quotes that produce a PO		

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LSS project roadmap (detailed version)

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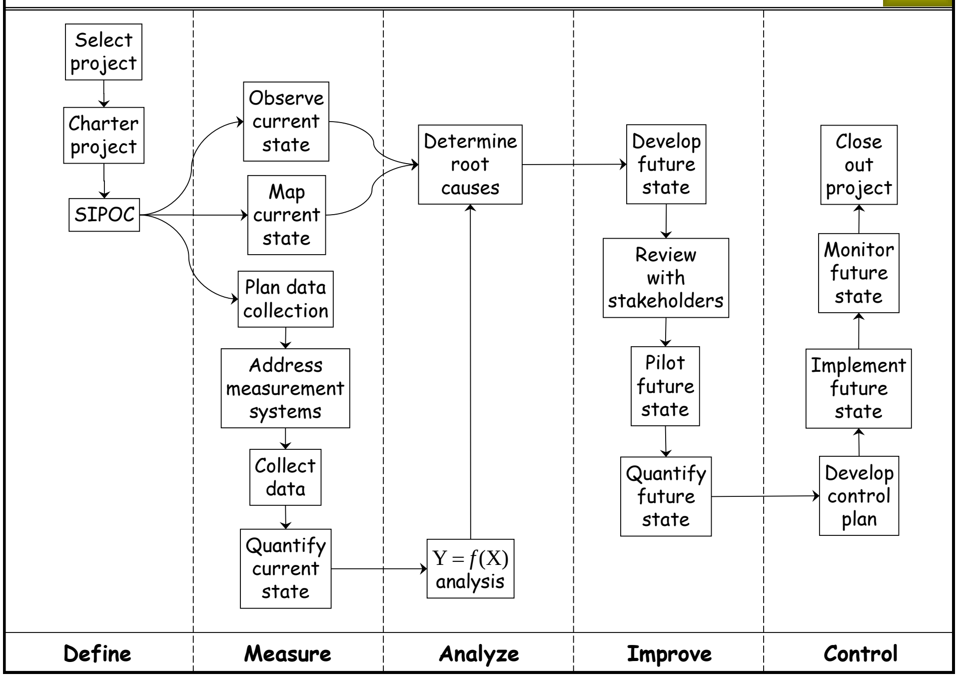

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4 LSS Case Study — Tool Development Process

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Background

- An extrusion supplier receives a blueprint for a new profile about once a day on average
- The supplier designs and machines the tools that will be used to extrude the profiles
- The supplier bears the development cost, then becomes the sole supplier for the life of the contract
- Once machined, a new tool is tested
- If necessary, it goes back to the machine shop for rework

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Define: problem statement

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Our tool development process has always been a problem. The number of reworks per new tool ranges from 0 to 20. Each rework takes about 3 days, so the order to sell time can be as long as 2 months. The cost per rework is about $1800, so the cost per tool can be as high as $36,000. We cannot compete on price with our overseas competition, so our only hope is to compete on quality and lead time.

Another problem is that the current tool development process results in manufacturing processes with relatively slow line speeds and excessive material usage.

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Define: project metrics and current values

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- Average cost per rework: $1800
- Average time per rework: 3 days
- Number of reworks per tool: 0 to 20
- Total rework cost per tool: up to $36,000
- Time from order to sell per tool: up to 2 months
- Average order to sell per tool: 9 days
- Annual cost of tool rework: $2.4 million

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Define: improvement goals

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- 50% reduction in average number of reworks per tool
- 50% reduction in average time from order to sell
- 50% reduction in annual cost of tool rework

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Define: project scope

Value stream scope

- Location A only
- PVC products only
- Out of scope: locations B & C, composite products
- These are **replication opportunities**

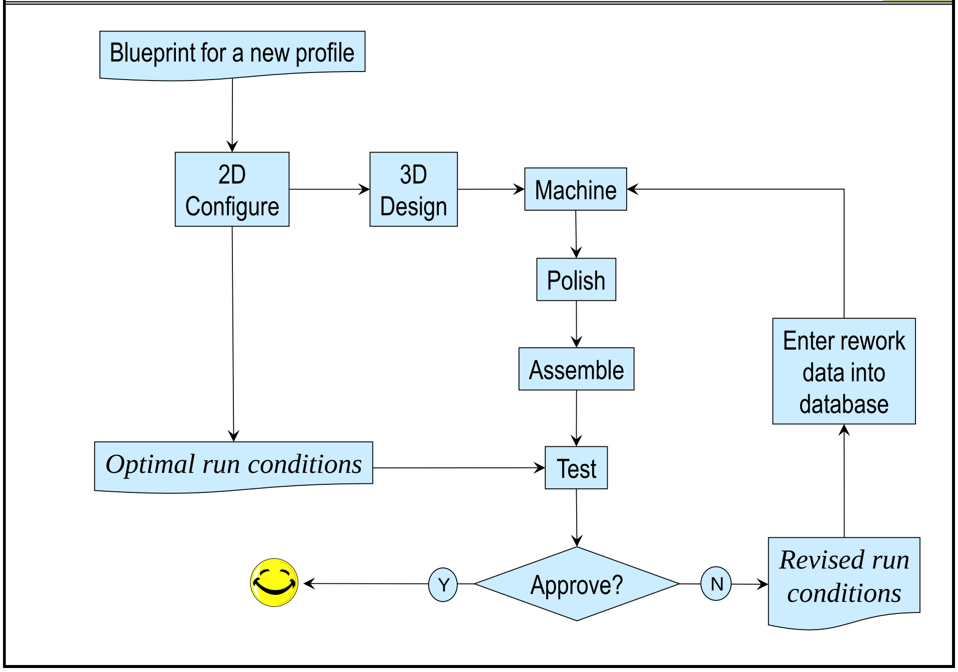
Workflow scope

- Starts with blueprint from external customer, ends with tool released to manufacturing

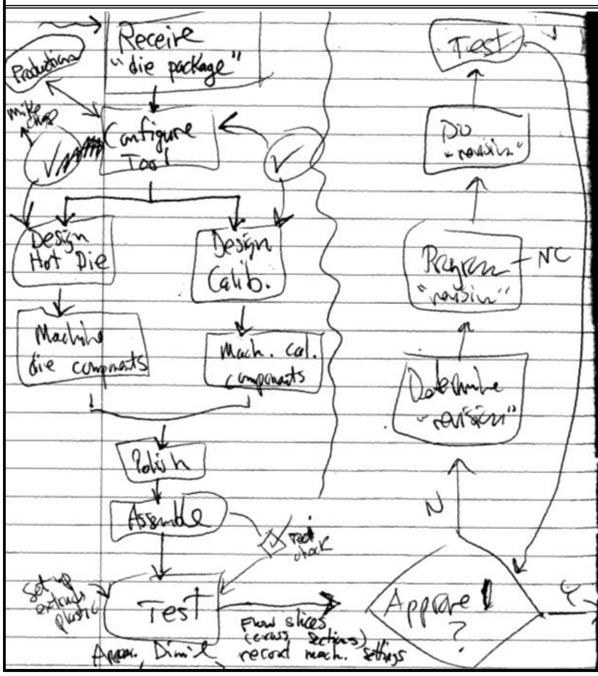
Define: project team

- Tool testing manager (also Champion)
- Quality manager
- Two engineers
- Two operators in the testing department

Measure: map the current state



Measure: map the current state



This is what the first draft looked like!

Measure: observe the current state

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- Testers are under pressure to work quickly (new profile comes in just about every day)
- Run conditions are modified by trial and error to solve dimensional or cosmetic problems
- Dimensional measurements to determine tool rework are taken with hand held calipers on plastic parts
- Testers ignore many of the run conditions specified in the 2D Configure process
- Testers often solve dimensional problems by decreasing the line speed and increasing the weight

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Measure: collect data

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Y variables (outputs of the process)

- Dimensions
- Cosmetic quality
- Number of reworks per tool
- Order-to-sell time per tool
- Line speed
- Weight

X variables (inputs to the process)

- Complexity of configuration
- Single or dual orifice die
- Dimensional tolerances
- Run conditions
- Tool testers

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Measure: calculate current-state metrics

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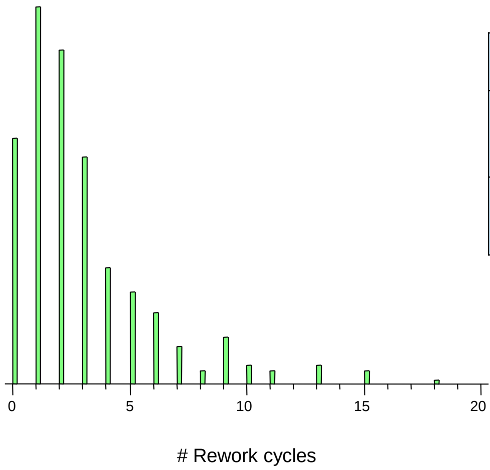
A year's worth of new tools



Sample size	339
Average number of rework cycles	3
Tools with 5 or more rework cycles	25%

Analyze: determine root causes

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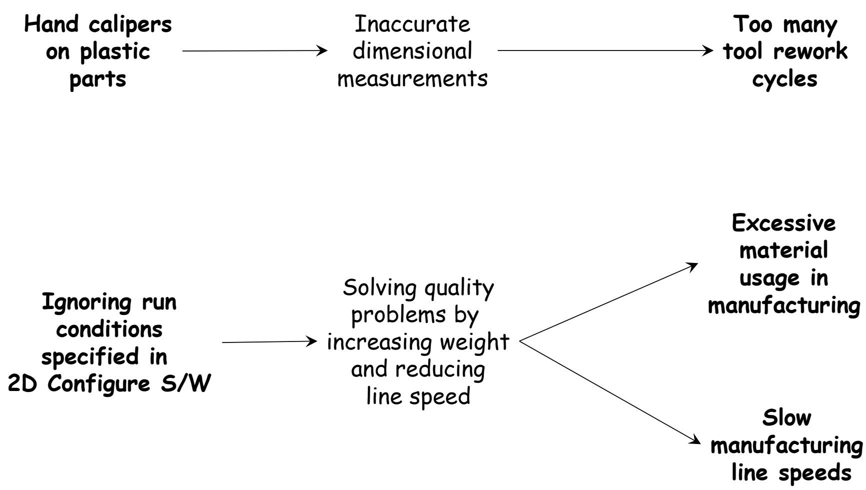

Analyze: correlate X variables to Y variables

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X variables				*Y variables*													
	Line		Die-cal.	Control dimensions													Distortion
Weight	speed	Vac.	dist.	1	2	3	4	5	6	7	8	9	10	11	12	13	rating
51	1	53	1	4	1	-13	0	1	-5	-5	9	-1	-11	-7	3	0	3
48	1	53	1	-1	4	-12	2	3	-2	-4	5	-1	-11	-11	0	-3	3
49	1	70	2	-4	4	-14	-4	1	-3	1	4	-5	-11	-9	3	0	4
48	1	70	2	1	1	-17	6	7	-5	0	5	-4	-11	-9	1	-4	3
81	1	67	1	0	-1	-12	6	1	-4	-3	5	2	-5	-1	11	3	1
76	1	67	1	0	4	-13	2	2	-7	-5	5	1	-6	-2	7	4	2
77	1	50	3	2	2	-12	1	-1	-5	-4	6	1	-7	-3	17	2	1
74	1	50	3	1	1	-16	3	1	-6	-5	13	1	-5	-4	8	1	2
48	2	77	1	-2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	-2	5
46	2	77	1	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2	4
47	2	50	3	-4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	3
45	2	50	3	-3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-4	4
67	2	67	2	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	4
64	2	67	2	-4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	4
67	2	80	3	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	3
65	2	80	3	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	4
77	2	50	1	-2	-2	-16	-4	0	-1	-4	6	-1	-8	-2	10	1	2
76	2	50	1	-4	-2	-14	-5	0	-2	-3	4	-1	-8	-1	7	3	3
78	2	80	2	-2	1	-14	-6	2	5	-3	3	-1	-8	-6	10	6	1
78	2	80	2	-3	-2	-15	-8	0	3	-1	4	-2	-9	1	9	4	3
49	3	67	1	0	3	-22	-2	5	-3	0	-1	-9	-14	-8	9	0	4
48	3	67	1	-5	-3	-22	-5	-1	-9	-4	1	-8	-15	-9	0	0	3
51	3	80	2	-2	-4	-22	-2	6	-7	0	1	-5	-13	-8	10	2	3
50	3	80	2	-1	-3	-20	-4	6	-4	1	1	-9	-14	-9	1	0	3
66	3	80	1	-5	3	-24	-4	4	-5	-3	-1	-6	-10	-4	7	4	4
66	3	80	1	2	-5	-19	1	7	-3	-1	1	-3	-11	-3	5	6	3

This analysis showed that testers could use variables other than weight and line speed to solve dimensional problems

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Improve: develop the future state

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- Teach testers to use variables other than weight and line speed to solve dimensional problems
- Require special approval to change weight and line speed from the values determined in 2D Configure
- Allow testers more time to evaluate tools in each rework cycle (→ fewer rework cycles)
- Provide testers with DVT gages to measure dimensions with greater accuracy

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Improve: pilot the future state (one of several tools)

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	Current state	*Future state*
Weight	381	366 (4% decrease)
Line speed	129	200 (55% increase)
Problems	6 dimensions needed rework Serious distortion	5 dimensions needed rework No distortion

Control: implement and monitor the future state

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- Conduct training as needed
- Conduct periodic audits
- Determine control limits for:
  - ✓ Number of days to release
  - ✓ Number of rework cycles
- When either variable exceeds its control limit:
  - ✓ Find the cause
  - ✓ Take corrective action

Control: calculate benefits

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- More than 50% reduction in average number of reworks
- More than 50% reduction in average order to sell time
- Replication opportunities
  - ✓ Composite products (vs. PVC)
  - ✓ The other two locations
- Total annual savings (eventually): $2 million

Notes

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5 Define Phase of LSS

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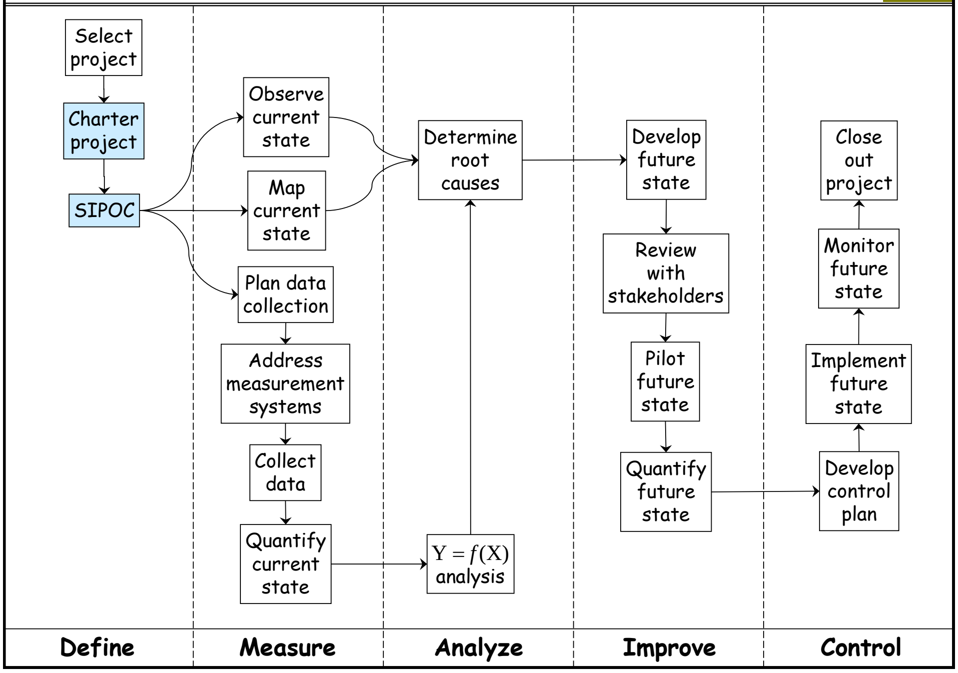

Project charter topics

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- Problem statement
- Value stream scope
- Workflow scope
- Inputs, outputs, customers, suppliers
- Project metrics
- Project teams
- Resources

Problem statement

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The problem statement should . . .

. . . Describe the current situation in objective terms

. . . Not suggest or imply solutions

. . . Locate the problem in time

. . . Include baseline values of project metrics, if possible

. . . Give enough information for "outsiders" to understand what the project is about

. . . Evolve and strengthen during the Define and Measure phases

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Notes

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Evolution of problem statements

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☹	😐	☺
We are upset with our customers for not paying us on time.	15% of invoices submitted to customers are paid more than 60 days late.	20% of invoices submitted to Stahl & Hyde last year were paid more than 60 days late. This compares to 5% for our other customers.
Due to lack of training in work cell Z, cycle times have trended up.	The average cycle time in work cell Z has increased from 30 minutes to 60 minutes.	In the last 6 months, the average cycle time in work cell Z during second shift has increased from 30 minutes to 90 minutes.

Evolution of problem statements (cont'd)

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☹	😐	☺
We are spending too much time searching for parts, paperwork, and supplies.	Over the last 3 months, searching for parts, paperwork, and supplies in the Assembly area has consumed 252 hours, equal to one half-time employee per month.	Over the last 3 months, searching for parts, paperwork, and supplies in the Assembly area has consumed 252 hours, equal to one half-time employee per month, or 7% of current FTEs. The burdened cost is $25K per month. These delays have added 3.8 hours to our average lead time.

Problem statement guidelines

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State the effect
Say who and what are affected, and how they are affected. Say what is wrong, not why it is wrong. Avoid "due to" or "because of" statements — they imply solutions.

Be specific
Avoid general terms like "morale," "productivity," "communication" and "training" — they tend to have a different meaning in each person's mind. Use specific, operationally defined terms to narrow the focus to the problem at hand.

Use positive statements
Avoid "lack of" statements (e.g., not enough, we need, we should). Negative statements imply solutions. Do not state a problem as a question — this implies that the answer to the question is the solution.

Quantify the problem
Say how much, how often, when, where. Use project benefit metrics.

Focus on the "gaps"
Compare the current levels of the project benefit metrics to previous levels, expected levels, or desired levels. Often this is covered in the goal statement.

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Problem statement checklist

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- ❑ Who is affected by the problem?
- ❑ What is happening?
- ❑ What are the "gaps"?
- ❑ What are the consequences of not solving the problem?
- ❑ Where does the problem occur?
- ❑ When does the problem occur?
- ❑ When did the problem start?

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Exercise 4: Problem statement critique - 1

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In 2008 there were 15 industrial accidents site wide. Previously, the annual average was 2.5 with at most 7 in a given year. This new level represents a significant decline in employee safety. If it continues, we will see a $200,000 increase in annual costs, and substantially decreased productivity.

Exercise 4: Problem statement critique - 1 (cont'd)

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- ❑ Who is affected by the problem?
- ❑ What is happening?
- ❑ What are the "gaps"?
- ❑ What are the consequences of not solving the problem?
- ❑ Where does the problem occur?
- ❑ When does the problem occur?
- ❑ When did the problem start?

Exercise 5: Problem statement critique - 2

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Critique this problem statement using the checklist on the next page. The important thing is to identify things that are missing.

> Customers are dissatisfied with telephone support wait times for calls handled through our call center in Uzbekistan. Our records show an average wait time of 8 minutes. 10% of wait times exceed 20 minutes.

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Exercise 5: Problem statement critique – 2 (cont'd)

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- ❑ Who is affected by the problem?
- ❑ What is happening?
- ❑ What are the "gaps"?
- ❑ What are the consequences of not solving the problem?
- ❑ Where does the problem occur?
- ❑ When does the problem occur?
- ❑ When did the problem start?

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Value stream scope

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Defines the project scope in terms of . . .

- ✓ Products
- ✓ Customers
- ✓ Suppliers
- ✓ Locations
- ✓ Materials

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Example - 1: Value stream scope

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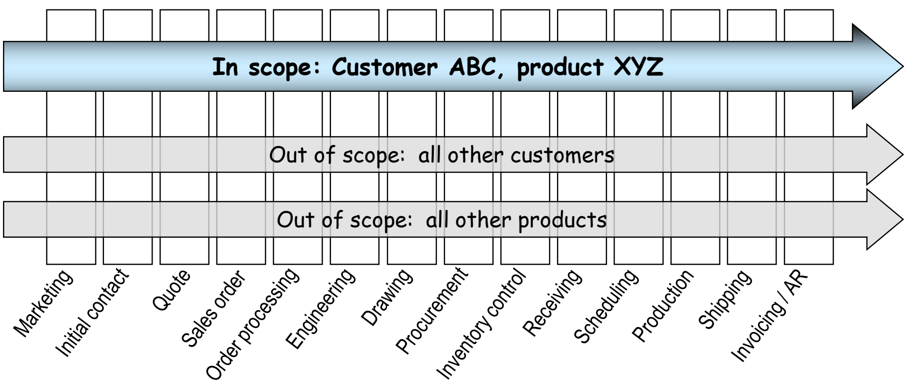

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Example - 2: Value stream scope for tool development process

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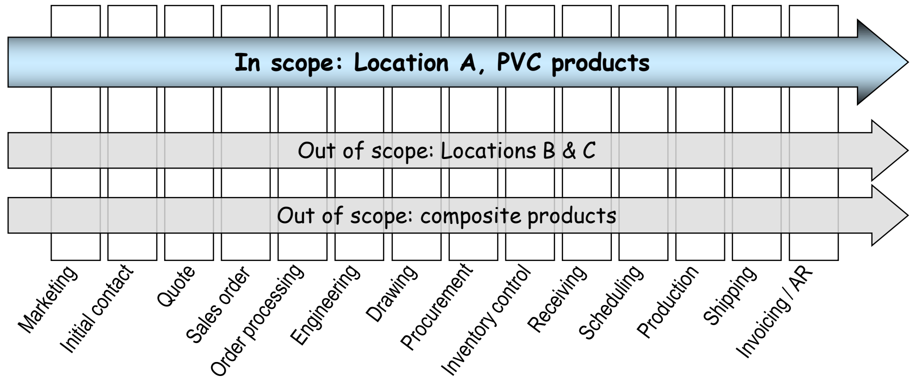

Workflow scope

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Defines the project scope in terms of . . .

- ✓ Activities
- ✓ Operations
- ✓ Processes
- ✓ Areas
- ✓ Departments

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Example - 1: Workflow scope

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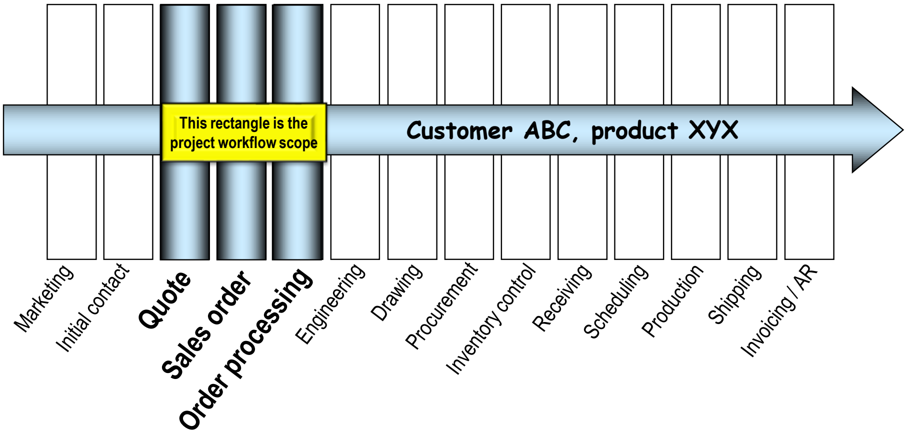
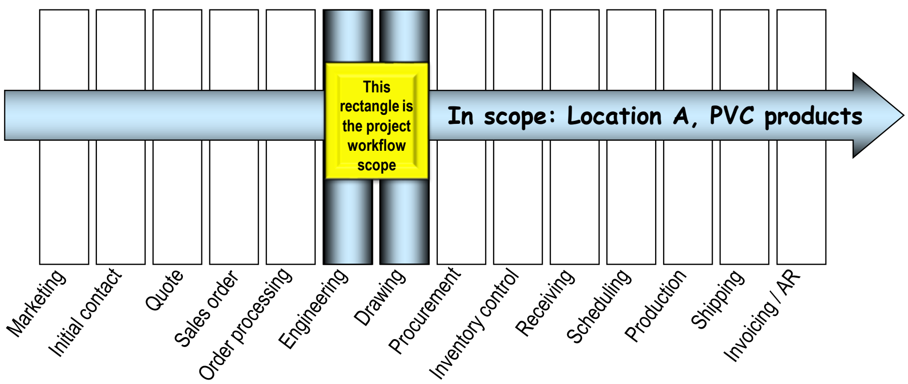
Imagine for this value stream scope that we want to initiate a project to improve Sales Order processing.
We also need to define the workflow scope:



Example - 2: Workflow scope for tool development process

66

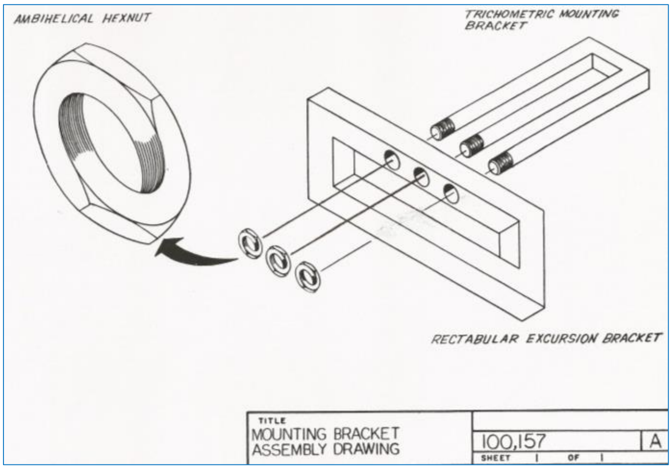


Exercise 6: Prototype development process

67

Our company makes prototypes for various types of mounting brackets. A project has been launched to reduce the lead time for designing and building prototypes for non-standard brackets. What is the value stream scope for this project?

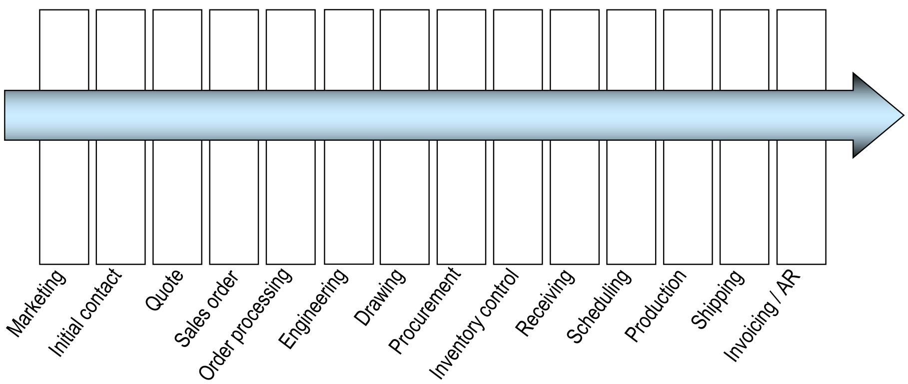
NON-STANDARD MOUNTING BRACKET



Exercise 6: Prototype development process (cont'd)

68

Name the in-scope value stream for prototype development:



Suppliers → Inputs → Process → Outputs → Customers

69

- **Customers** are entities outside the workflow boundaries who receive **outputs** from the workflow
- **Suppliers** are entities outside the workflow boundaries who provide **inputs** to the workflow
- Customers and suppliers are determined by the workflow boundaries
- If we change the boundaries, the customers and suppliers will change

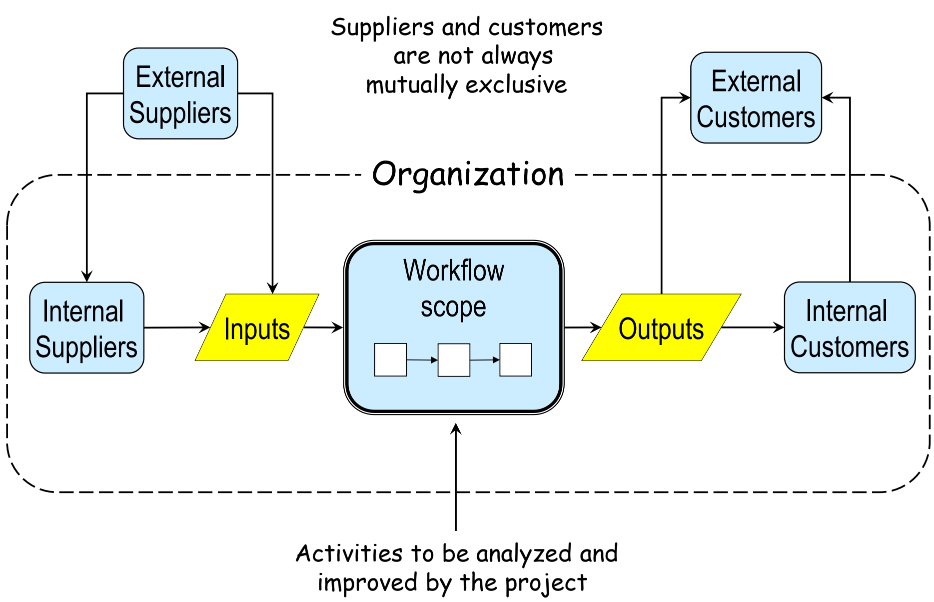
Discussion questions

a) Why is it important to think about the customers of a workflow we want to improve?

b) Why is it important to think about the suppliers to a workflow we want to improve?

Suppliers → Inputs → Process → Outputs → Customers

70



Exercise 7: SIPOC for prototype development process

71

Our company makes prototypes for various types of mounting brackets. A project has been launched to reduce the lead time for designing and building prototypes for non-standard mounting brackets. Use the information given in the next slide to answer the following questions:

(a) What are the outputs from this workflow?

(b) Who are the customers that receive these outputs?

(c) What are the inputs to this workflow?

(d) Who are the suppliers that provide these inputs?

(e) What is the workflow scope for this project?

Exercise 7: SIPOC for prototype development process (cont'd)

72

When a customer sends us a purchase order (PO) to design and build a prototype for a non-standard bracket, they provide us with the functional requirements, specifications, a sketch, and desired delivery date. We begin by developing a design specification for the desired bracket. The customer must approve the design specification. If they do, we develop an assembly drawing, which the customer does not have to approve. We build the prototype from the assembly drawing, test it for conformance to the functional requirements and specifications, then ship it to customer.

Sometimes a customer will order a quantity of production parts based on an approved prototype. When this happens, the drawing is released to Manufacturing (MFG).

Project metrics

73

- Calculated from *statistical data* relevant to project objectives
  - ✓ Averages
  - ✓ Percentages
- Validated *financial calculations* relevant to the project objectives
  - ✓ Annual cost of ______
- Should be linked to *key performance indicators*
  - ✓ Customer satisfaction – quality
  - ✓ Customer satisfaction – delivery
  - ✓ Cost reduction
  - ✓ Revenue increase
  - ✓ Safety . . .

73

Project metrics (cont'd)

74

Example - 1: Sales Order Processing

Project metrics	Baseline	Goal
Quote turn around time (TAT)	5 days	50% reduction
% Lost bids	40%	50% reduction
% of Scrap caused by SO processing errors	7%	50% reduction
Annual cost of SO rework ("do-overs")	$50K	70% reduction

Example - 2: Tool Development Process

Project metrics	Baseline	Goal
Annual cost of tool testing	$2.4M	$1.2M
Avg. number of reworks	3	1.5
Avg. order-to-sell time	9 days	4.5 days
Avg. line speed	130	200
Avg. weight	110% of customer target	95% of customer target

74

Project teams

75

Definition of "team"

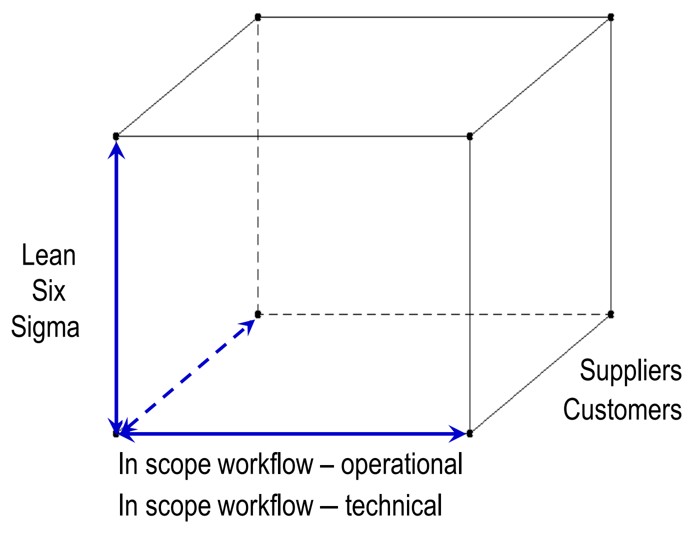
- A small number of people with complementary skills committed to a common purpose or objective.
- They hold themselves mutually accountable for achieving the objective.
- Coordination of activity among team members is required to achieve the objective.

75

Team composition

76

Multiple dimensions of knowledge are needed



76

Resources

77

A project team needs certain things in order to succeed

- Members from the in-scope workflow
- Members from internal customers and/or suppliers
- Validated financial calculations
- Data downloads
- A place to have regular meetings
- Coaching on application of LSS methods

⋮

77

Resources (cont'd)

78

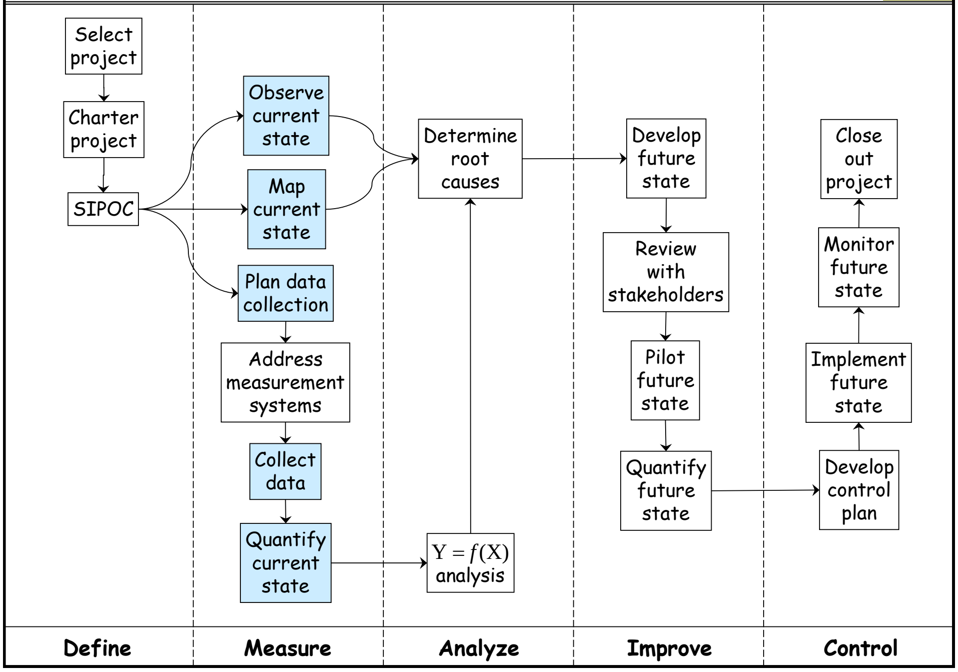
A resource is someone who can provide things the team needs

- Project champion
- Area manager or supervisor
- Financial analyst
- IT person
- Facilities
- HR
- Master Black Belt

78

6 Measure Phase of LSS

79



79

Topics

80

- Observing the workflow
- Process mapping
- Common mapping formats
- Planning data collection
- Calculating statistical metrics

80

Observing the workflow

81

- Take a guided tour
- Interview workflow participants
- Uncover the "hidden factory"
- Identify opportunities for improvement
- Begin drafting process map(s)

81

Guidelines

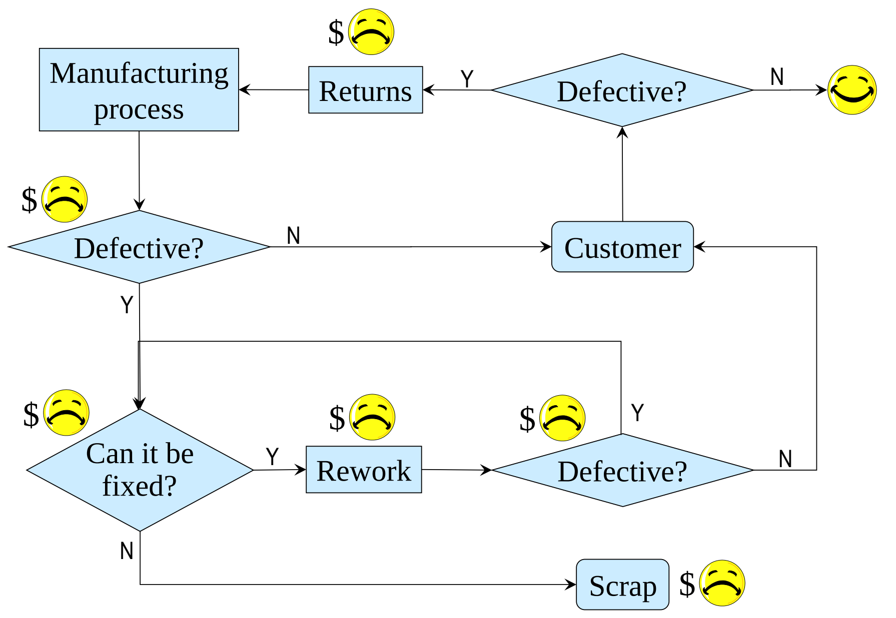
82

- Scope and boundaries should match the project charter
- Workflow participants must have advance notice
- The project and its objectives must be explained (preferably ahead of time)
- The purpose is to gain information related to the project
- Auditing work performance is *not* the purpose — it's a *treasure hunt*, not a witch hunt!
- Try to minimize the "thundering herd" syndrome

82

The “hidden factory”

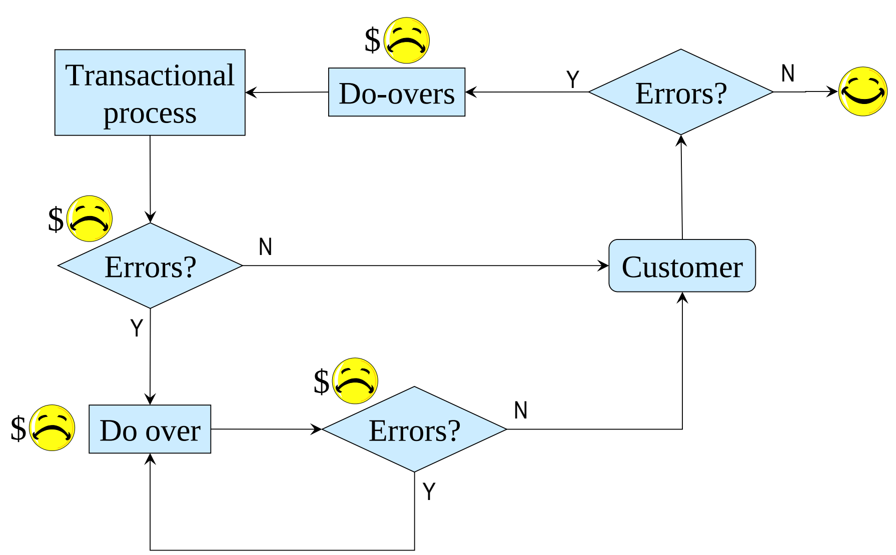
83



83

What about the “hidden office”?

84



84

Process mapping

85

- Appealing, energizing team activity
- Easy to learn, results in useful products
- Graphically documents the in scope workflow – inputs, outputs, sequence and relationship of activities and decisions
- Shows what actually happens, not what should happen
- Identifies opportunities for improvement

85

Process map boundaries

86

Your project charter should identify the boundaries of your target process. This boundary setting occurs at several levels, first with the value stream scope, then workflow scope.

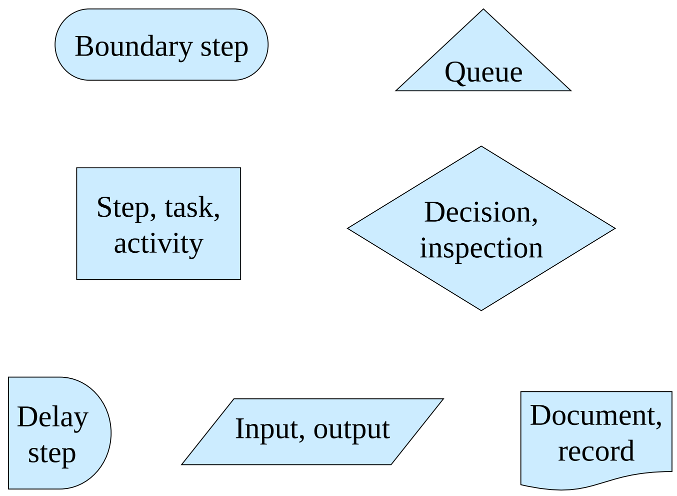
Building off the workflow scope, the first, last, and main intermediate steps of the target process give you a *high-level process map*.

This outlining is the starting point for *detailed process maps* showing the component tasks and decisions for some or all of the main steps.

86

Standard flowcharting symbols

87



Mapping as a team activity

88

Suspend your disbelief	Map the workflow the way it really is, not the way you think it should be.
Don't make assumptions	If you don't know what happens at a certain point, or can't agree on what happens, put a question mark there. Then, go ask someone who does know.
Solicit feedback	Ask in scope workflow participants, and their internal customers, to review the map for accuracy and clarity.

Writing good narrative

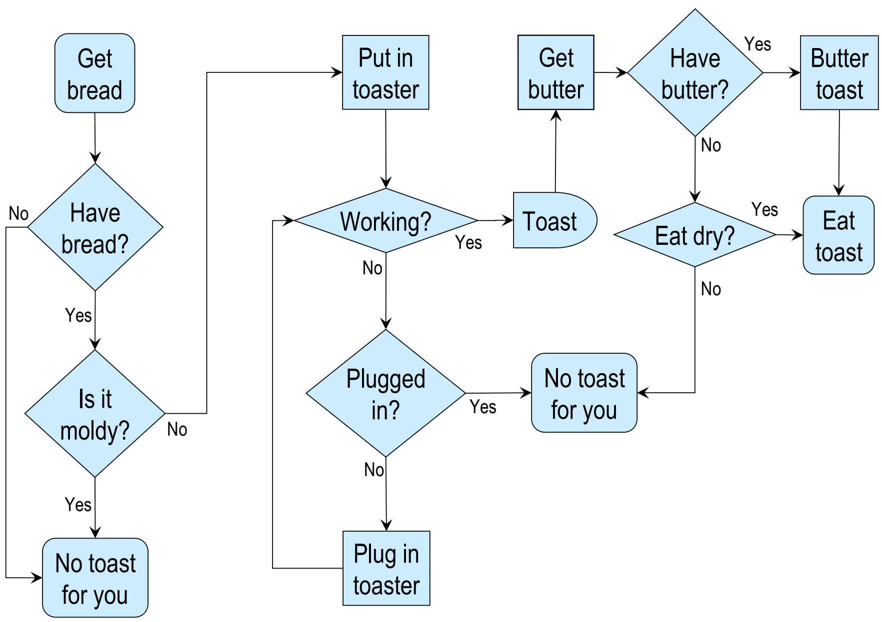
89

- ✓ Use active voice, not passive voice
  - ☹ Order is entered
  - ☺ Enter the order
- ✓ Use verb/object, not name of activity
  - ☹ Order Entry
  - ☺ Enter the order
- ✓ Use short sentences with familiar words
  - ☹ Twilight's last gleaming
  - ☺ Dusk
- ✓ Use present tense
- ✓ Use logical, consistent layout

89

Decision steps show what really happens

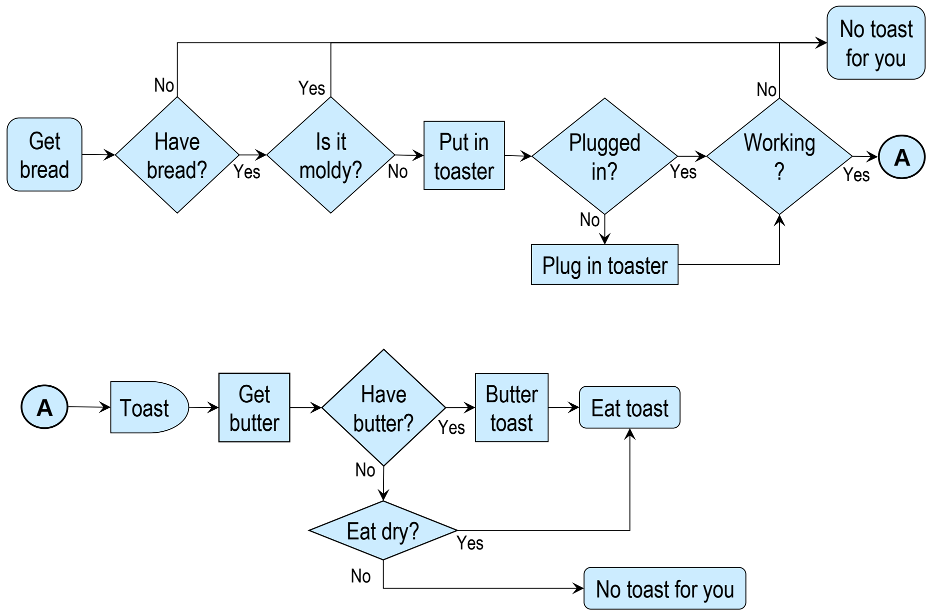
90



90

Best practice: follow a qualitative timeline

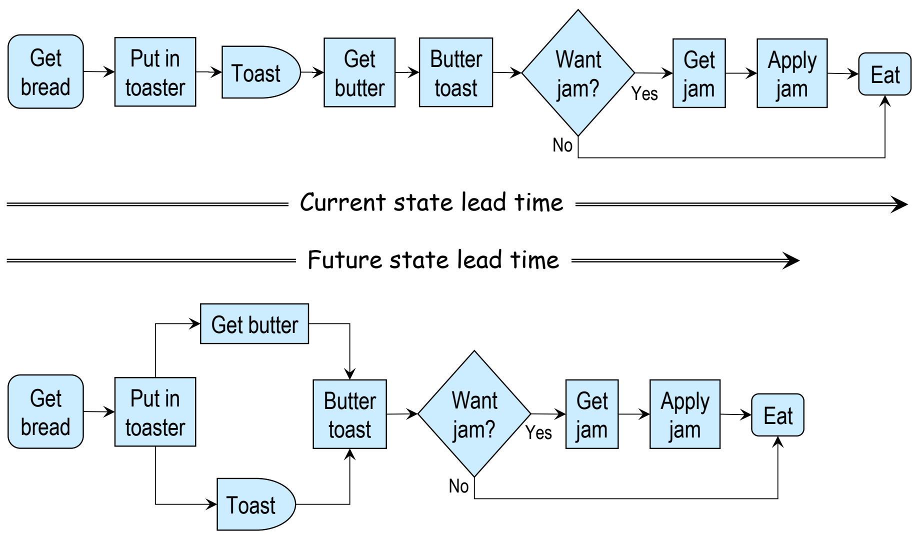
91



Parallel activities

92

Common technique for reducing lead time: convert *serial* to *parallel*



How could we further reduce the lead time for making toast?

Exercise 8: Process Map

93

Create a process map based on the information given here. Do not make unwarranted assumptions! The instructor will provide guidance on options for creating the map either digitally or in hard copy.

You have two types of material, A and B. When the need arises, take the material to a processing center. There are two steps in the process. For Process 1, the A and B materials must be processed in separate Type 1 machines. If there are two Type 1 machines available, load the A material into one machine, the B material into another, and run the two machines at the same time. If there is only one machine available, you have to run the two loads sequentially.

When Process 1 is completed, move on to Process 2. Process 2 requires Type 2 machines. If there are two Type 2 machines available, load the A material into one machine, the B material into another, and run the two machines at the same time. If there is only one machine available, you can process the A and B material together in the same machine. This will take longer than processing the A and B materials in separate machines, but not as long as running two loads sequentially. When Process 2 is completed, organize the material in an orderly configuration, take it back to your original location, and store it for subsequent use.

93

Notes

94

94

Common mapping formats

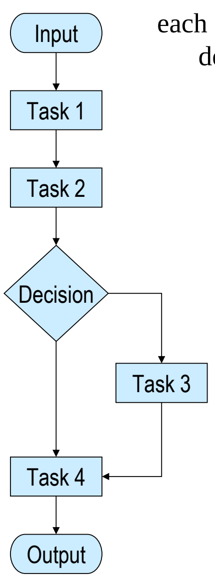
95

- Simple
- Cross-functional (aka Swimlane)
- Geographic (aka Spaghetti)
- Topological

95

A simple process map

96



Who is responsible for each activity and decision?

Could make a table:

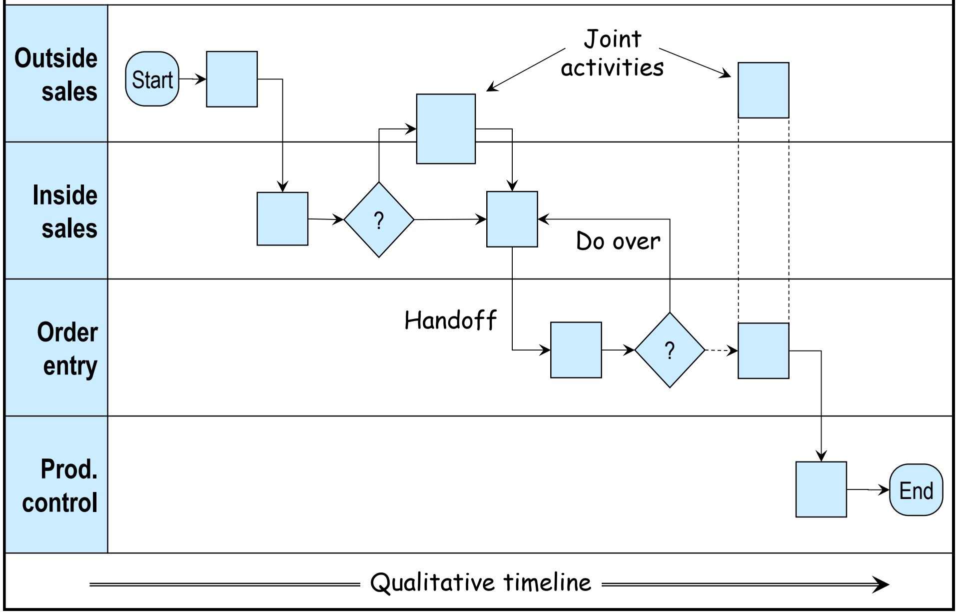
	Responsible party
Input	
Task 1	
Task 2	
Decision	
Task 3	
Task 4	
Output	

96

Cross functional map

97

Also known as a *swimlane map*



Cross functional map (cont'd)

98

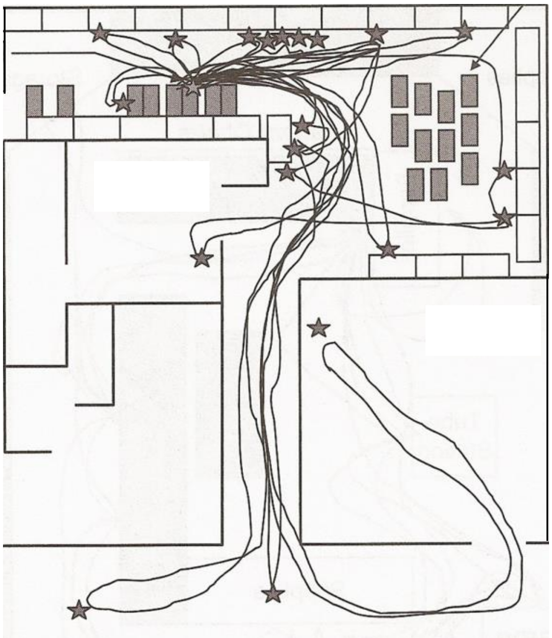
A cross functional map visually portrays the responsibilities for all process activities and decisions. In addition to showing responsibilities, cross functional maps are much better than simple maps for identifying opportunities for improvement.

To draw a cross functional map, first determine all the departments or functions involved in the activities and decisions you want to map. Enter swimlanes for departments or functions from top to bottom in the order they are first called for in the sequence of activities and decisions. Also, you should follow a qualitative timeline in placing activities and decisions on the map.

With this method, the general flow of the activities and decisions will be from Northwest to Southeast on the map. This usually leads to the simplest and easiest to read depiction of the process.

Geographic map

99

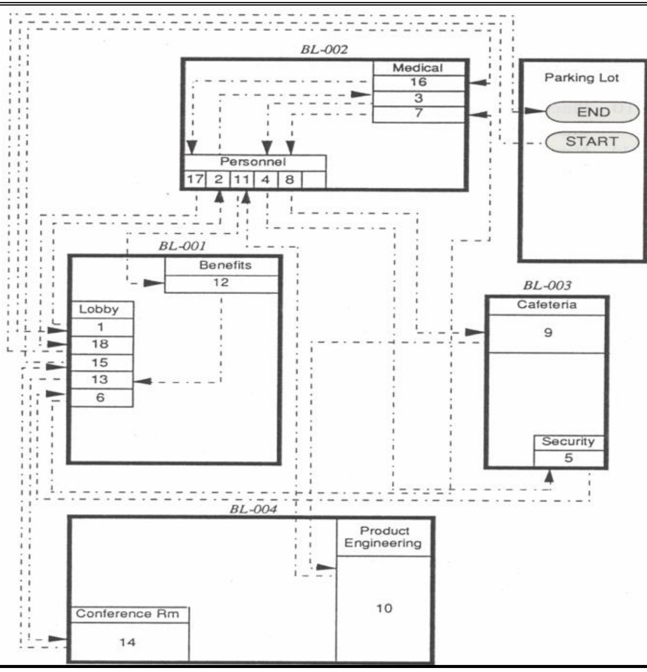


- Also known as *spaghetti diagram*
- Requires a floor plan or scale drawing
- Show typical travel patterns
- Quantify distance travelled

99

Large scale geographic map

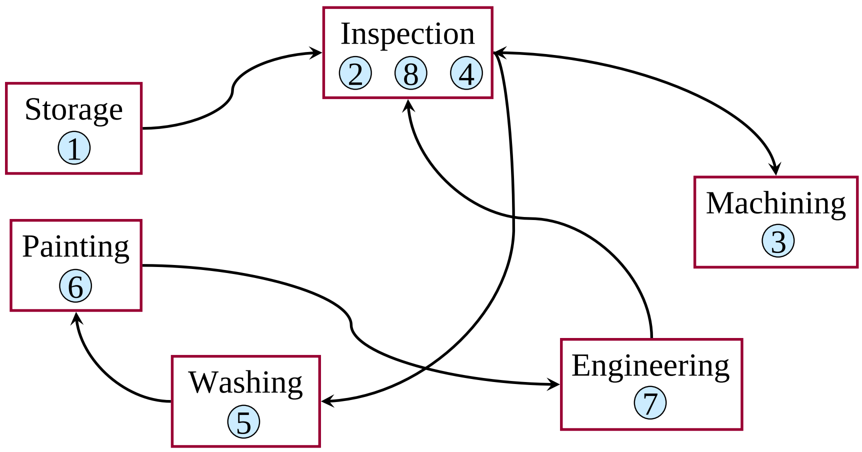
100



100

Geographic map: current state

101

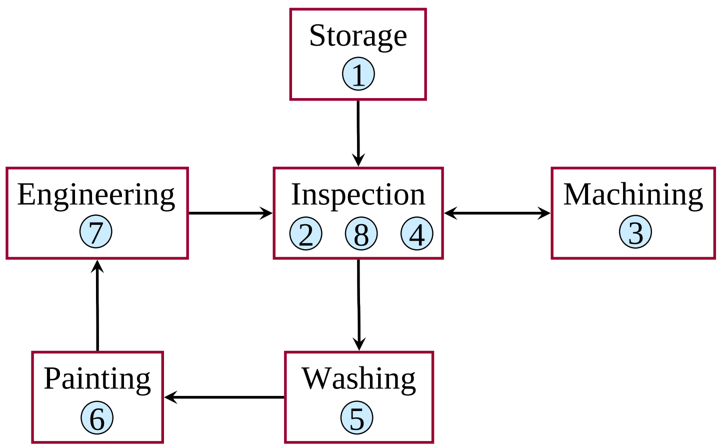


- Too much transport
- Should rearrange to minimize transport

101

Geographic map: future state

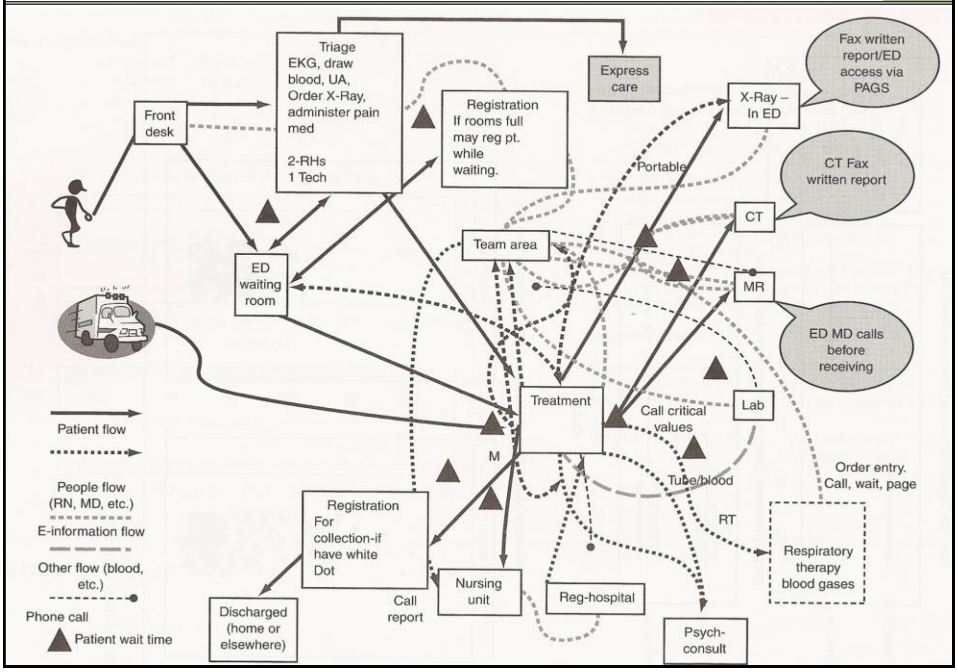
102



102

Emergency Department (ED) Topological map of patient flow

103



103

ED patient flow (cont'd)

104

topological *adj* **:** concerned with relations between objects abstracted from exact quantitative measurement

A topological map is similar to a spaghetti diagram, but without the geography/scale. It shows connections, but not distances. It may or may not indicate a time or process sequence. The routing diagrams in the London Underground are famous examples of topological maps.

The ED patient flow map shows the flow of patients, staff, and information or patient specimens in a hospital Emergency department.

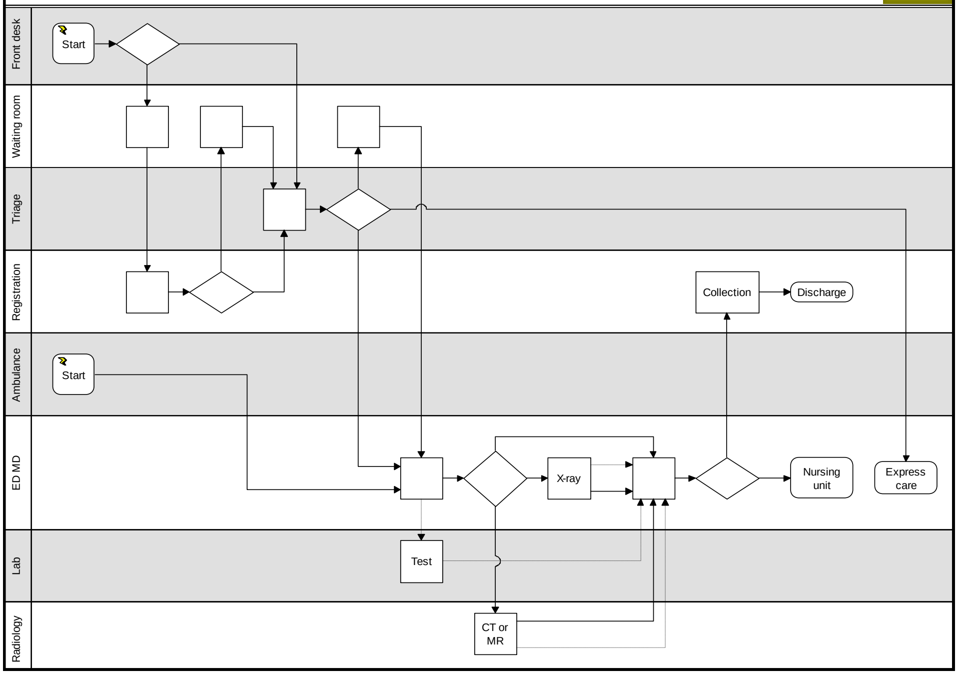
Like geographic maps, topological maps are extremely effective for conveying the complexity of a process. Also, the free form nature of topological mapping lends itself to team brainstorming.

On the other hand, we often need information on the sequence and location of process steps to move beyond the first impression of complexity. Topological mapping is typically not a very good format for displaying this kind of information.

104

ED patient flow in swimlane format

105



ED patient flow swimlane format (cont'd)

106

- Swimlane diagram of the same patient/information flow
- Shows the back and forth among different areas
- Gives a visual representation of the time sequence
- Clearly defines the possible patient pathways
- Solid arrows represent movement of the patient
- Dotted arrows represent movement of patient information, test results, X rays, blood samples, etc.
- Easier to follow

Exercise 9: Process Map for prototype development process

107

The instructor will divide the class into teams. Each team is to create a cross functional process map of the prototype development process described on the next pages.

The instructor will provide guidance on options for creating the map either digitally or in hard copy.

Enter swimlanes (departments) as they occur in the narrative.
(If using "sticky notes," make the swimlanes at least two sticky notes wide.)

Add a sticky note for *each* step or decision in the process, although it's recommended to combine QE and ME in one lane.

You'll need to add flow lines as you go; draw them lightly and wait until your map is finished to make them permanent.

Notes

108

Exercise 9: Process Map for proto development process (cont'd)

109

When a customer sends Sales a purchase order (PO) to produce a prototype for a non-standard bracket, Sales meets with Product Engineering (PE) to review the functional requirements, specifications, sketch, and desired delivery date. PE creates an initial design specification, then reviews it with the customer. If the customer is not satisfied, PE makes the required changes, then meets with the customer again.

After the customer approves the design spec, copies go to Quality Engineering (QE) and Manufacturing Engineering (ME) for review. If either group has any problems with it, PE makes the required changes, then meets with the customer again. If the customer is happy with the revised design spec, copies go back to QE and ME.

After QE and ME approve the design spec, it goes to Drafting to create an assembly drawing. The first draft goes to PE for review. If PE is not satisfied with the drawing, it goes back to Drafting for revision, then back to PE.

After PE approves the drawing, it goes to QE and ME for review. If either group has any problems with it, it goes back to Drafting to make the required changes. Drafting sends the drawing back to PE for review. If PE is satisfied with the changes, the drawing goes back to QE and ME again.

109

Exercise 9: Process Map for proto development process (cont'd)

110

After QE and ME approve the drawing, it goes to Proto. This is a special production area, separate from manufacturing, whose purpose is to build prototypes quickly. The Proto operators have a lot of experience and can build almost anything.

Proto builds the prototype, then tests it for conformance with the functional requirements and specifications. If the prototype passes the tests, PE arranges for it to be shipped to the Customer.

What happens if a prototype fails one or more of the tests? No one on the team seems to know.

110

Planning for data collection

111

- Why do we need data?
- Project metrics and underlying data
- Types of data
- Y variables and X variables
- Operational definitions
- Getting representative data

Why do we need data?

112

"If you don't measure it, you don't understand it.

If you don't understand it, you can't improve it."

If that doesn't work, try this:

"In God we trust. All others, bring data."

Case Study — Tool Development: Project metrics & underlying data

113

Metric	*Data*
Average number of rework cycles	Number of rework cycles for each tool, for some number of tools
Average order to sell time	Order to sell time for each tool, for some number of tools
Average weight of shipments	Weight of each shipment, for some number of shipments
% of shipments exceeding an upper limit	
Average time from purchase order (PO) to prototype delivery (PD)	PO-PD time for each prototype, for some number of prototypes
% PO-PD time exceeding 25 days	

General: Project metrics and underlying data

114

Metric	*Data*
Average lead time	Lead time for each part or transaction, for some number of parts or transactions
% of lead times exceeding an upper limit	
% Defective	Defective (Y/N) for each part, for some number of parts
Average number of errors	Number of errors in each transaction, for some number of transactions
Average bond strength	Strength of each bond, for some number of bonds
% of bond strengths below a lower limit	

Types of data

115

	Also known as	*Examples*
Quantitative	Measurement Continuous Parameter Variable	Properties (physical/chemical/electrical/optical) Dimensions Distance Time Counts
Categorical	Qualitative Attribute Nominal Ordinal	Pass/fail, failure modes Quality ratings Customer, supplier, product Machine, operator Method, type Batch, lot, work order, serial number Time period

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Notes

116

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Exercise 10: Types of data

117

Pretend that the table on the next slide contains actual data on actual cars (as opposed to nominal values published by manufacturers). Check the appropriate data type for each variable.

Are there any that could go either way?

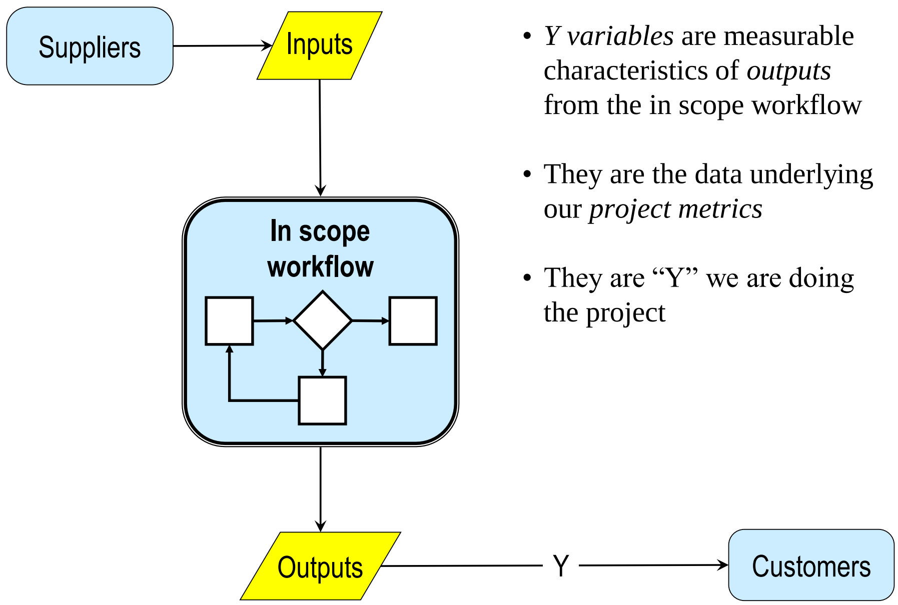
	Quantitative	Categorical
Model year		
Origin		
Make		
Model		
Cylinders		
Displacement		
Horsepower		
Weight		
Accel		
MPG		

Exercise 10: Types of data (cont'd)

118

Model year	Origin	Make	Model	Cylinders	Displace	Horsepower	Weight	Accel	MPG
79	Europe	Mercedes	300D	5	183	77	3530	20.1	25.4
80	Europe	Mercedes	240D	4	146	67	3250	21.8	30.4
79	America	Cadillac	Eldorado	8	350	125	3900	17.4	23.0
81	Japan	Toyota	Cressida	6	168	116	2900	12.6	25.4
81	Europe	Volvo	Diesel	6	145	76	3160	19.6	30.7
81	Europe	Peugeot	505S DI	4	141	80	3230	20.4	28.1
82	America	Chevrolet	Camaro	4	151	90	2950	17.3	27.0
81	Japan	Datsun	810 Maxima	6	146	120	2930	13.8	24.2
81	Europe	Saab	900S	4	121	110	2800	15.4	
80	Japan	Datsun	280-ZX	6	168	132	2910	11.4	32.7
80	Europe	Audi	5000S DI	5	121	67	2950	19.9	36.4
82	Japan	Toyota	Celica GT	4	144	96	2665	13.9	32.0
82	America	Oldsmobile	Cutlass DI	6	262	85	3015	17.0	38.0
82	America	Buick	CenturyLmt	6	181	110	2945	16.4	25.0
80	Japan	Mazda	RX-7 GS	3	70	100	2420	12.5	23.7
80	Europe	Volkswagen	Rabbit	4	98	76	2144	14.7	41.5
80	Europe	Volkswagen	Rabbit	4	89	62	1845	15.3	29.8
81	America	Oldsmobile	Cutlass LS	8	350	105	3725	19.0	26.6
81	America	Buick	Century	6	231	110	3415	15.8	22.4
82	Japan	Honda	Accord	4	107	75	2205	14.5	36.0
82	Japan	Nissan	Stanza XE	4	120	88	2160	14.5	36.0

Y variables



- *Y variables* are measurable characteristics of *outputs* from the in scope workflow
- They are the data underlying our *project metrics*
- They are "Y" we are doing the project

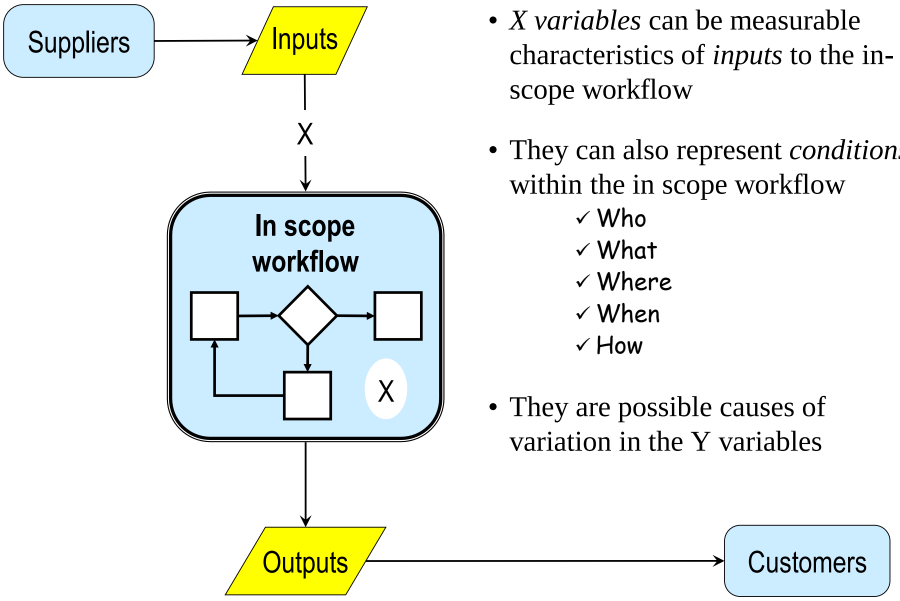
Case Study — Tool Development: Examples of Y variables

Project Title	Tool Testing Process Improvement
Project Scope	PVC products only, not composite

Process boundaries	Outputs	Y variables	Customers
Starts with a blueprint from external customer defining the desired profile. Ends with an approved tool and run conditions released to manufacturing.	Approved tool	Number of revisions Order to sell time	Manufacturing External customer
	Run conditions	Line speed Weight	Manufacturing
	Samples of extruded product with desired profile	Dimensions Cosmetic quality rating	External customer

X variables

121



- *X variables* can be measurable characteristics of *inputs* to the in-scope workflow
- They can also represent *conditions* within the in scope workflow
  - ✓ Who
  - ✓ What
  - ✓ Where
  - ✓ When
  - ✓ How
- They are possible causes of variation in the Y variables

121

Case Study — Tool Development: Examples of X variables

122

Project Title	Tool Testing Process Improvement
Project Scope	PVC products only, not composite

Suppliers	Inputs	X variables	Workflow boundaries	X variables
External customer	Blueprint	Profile complexity Single or dual orifice Dimensional tolerances	Starts with a blueprint from external customer defining the desired profile. Ends with an approved tool and run conditions released to manufacturing.	Which tester Which machine Material (PVC or composite)
External suppliers	Raw materials	Cost Quality Delivery		

122

Exercise 11: Y variables

123

We want to do a study of automotive performance using the data set below. Which are the Y variables?

Model year	Origin	Make	Model	Cylinders	Displace	Horsepower	Weight	Accel	MPG
79	Europe	Mercedes	300D	5	183	77	3530	20.1	25.4
80	Europe	Mercedes	240D	4	146	67	3250	21.8	30.4
79	America	Cadillac	Eldorado	8	350	125	3900	17.4	23.0
81	Japan	Toyota	Cressida	6	168	116	2900	12.6	25.4
81	Europe	Volvo	Diesel	6	145	76	3160	19.6	30.7
81	Europe	Peugeot	505S DI	4	141	80	3230	20.4	28.1
82	America	Chevrolet	Camaro	4	151	90	2950	17.3	27.0
81	Japan	Datsun	810 Maxima	6	146	120	2930	13.8	24.2
81	Europe	Saab	900S	4	121	110	2800	15.4	
80	Japan	Datsun	280-ZX	6	168	132	2910	11.4	32.7
80	Europe	Audi	5000S DI	5	121	67	2950	19.9	36.4
82	Japan	Toyota	Celica GT	4	144	96	2665	13.9	32.0
82	America	Oldsmobile	Cutlass DI	6	262	85	3015	17.0	38.0
82	America	Buick	CenturyLmt	6	181	110	2945	16.4	25.0
80	Japan	Mazda	RX-7 GS	3	70	100	2420	12.5	23.7
80	Europe	Volkswagen	Rabbit	4	98	76	2144	14.7	41.5
80	Europe	Volkswagen	Rabbit	4	89	62	1845	15.3	29.8

123

Gathering representative data

124

- More data is better than less
- Longer time period is better than shorter
- Try to cover all the *typical sources of variation*, often categorized using the “6 M’s”
- This method usually gives you a representative sample of adequate size

124

Gathering Representative data (cont'd)

125

Typical sources of variation

Process participants

"Identical" pieces of equipment

Time of day, week or month

Batches or lots of raw material or components

Different suppliers

Production lots, work orders, . . .

Different locations

Changing environmental conditions

Inconsistent practices/procedures

Multiple measurement systems

What are the "6 M" categories represented in this list?

Calculating statistical metrics

126

- Pass/fail data — percent failing
- Quantitative data — average *and* percent failing

Recording pass/fail data

127

- Create a data collection form (see example to the right)
- Enter the number of items tested and the number failed for each time period (hourly, for each shift, daily, weekly – whatever makes sense)
- When finished, calculate the column totals
- Divide the total failed by the total tested to get the % failing

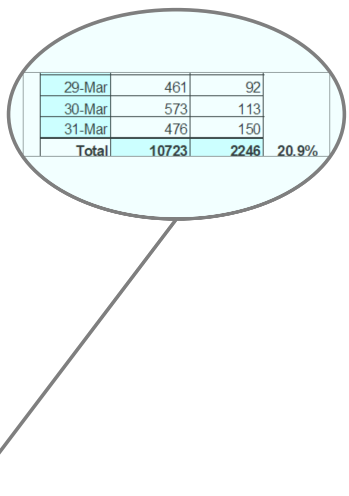
Test Date	No. Tested	No. Failed
1-Mar		
2-Mar		
3-Mar		
6-Mar		
7-Mar		
8-Mar		
9-Mar		
10-Mar		
13-Mar		
14-Mar		
15-Mar		
16-Mar		
17-Mar		
20-Mar		
21-Mar		
22-Mar		
23-Mar		
24-Mar		
27-Mar		
28-Mar		
29-Mar		
30-Mar		
31-Mar		
Total		

127

Calculating metrics for pass/fail data

128

Test Date	No. Tested	No. Failed	
1-Mar	492	59	
2-Mar	454	50	
3-Mar	228	45	
6-Mar	489	117	
7-Mar	463	106	
8-Mar	432	79	
9-Mar	466	80	
10-Mar	362	42	
13-Mar	433	77	
14-Mar	502	155	
15-Mar	467	91	
16-Mar	572	141	
17-Mar	455	109	
20-Mar	496	135	
21-Mar	533	130	
22-Mar	554	166	
23-Mar	469	69	
24-Mar	467	104	
27-Mar	424	73	
28-Mar	455	63	
29-Mar	461	92	
30-Mar	573	113	
31-Mar	476	150	
Total	**10723**	**2246**	**20.9%**



Percent defective

20.9%

128

Recording quantitative data

- Create a data collection form (see example shown below)
- Record the value for each time period or part
- Calculate the average value*
- Calculate the percent of values that are too high &/or too low

		Day		
		1	2	3
Time of day	7:00			
	9:00			
	11:00			
	13:00			
	15:00			
	17:00			
	19:00			

*Add them up, divide by how many there are.

Calculating metrics for quantitative data

		Day		
		1	2	3
Time of day	7:00	1370	1312	1438
	9:00	1462	1405	1506
	11:00	1437	1398	1574
	13:00	1476	1466	1440
	15:00	1389	1406	1372
	17:00	1288	1459	1267
	19:00	1304	1369	1395

Average = **1406.3**

Calculating metrics for quantitative data (cont'd)

131

		Day		
		1	2	3
Time of day	7:00	1370	1312	1438
	9:00	1462	1405	1506
	11:00	1437	1398	1574
	13:00	1476	1466	1440
	15:00	1389	1406	1372
	17:00	1288	1459	1267
	19:00	1304	1369	1395

Lower Spec = 1350

% Defective = **19.0%**

(Values below 1350 occurred 4 out of 21 days)

131

Notes

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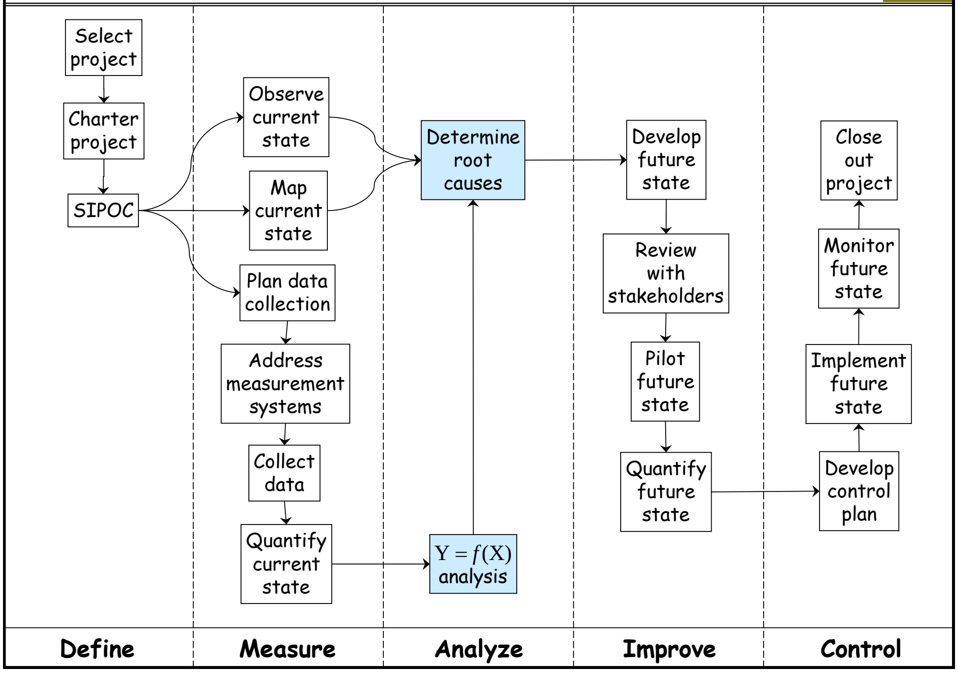
7 Analyze Phase of LSS

133



133

Topics

134

- Run chart from pass/fail data
- Pareto chart of failure modes
- Stratification with pass/fail data
- Run chart from quantitative data
- Stratification with quantitative data
- Root cause analysis

134

Run chart from pass/fail data

135

We want to look for a trend in daily failure rates

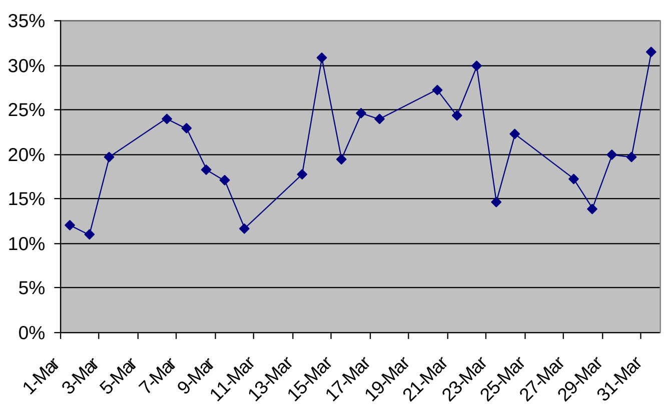
Test Date	No. Tested	No. Failed	
1-Mar	492	59	
2-Mar	454	50	
3-Mar	228	45	
6-Mar	489	117	
7-Mar	463	106	
8-Mar	432	79	
9-Mar	466	80	
10-Mar	362	42	
13-Mar	433	77	
14-Mar	502	155	
15-Mar	467	91	
16-Mar	572	141	
17-Mar	455	109	
20-Mar	496	135	
21-Mar	533	130	
22-Mar	554	166	
23-Mar	469	69	
24-Mar	467	104	
27-Mar	424	73	
28-Mar	455	63	
29-Mar	461	92	
30-Mar	573	113	
31-Mar	476	150	
Total	**10723**	**2246**	**20.9%**

Test Date	No. Tested	No. Failed	
1-Mar	492	59	12.0%
2-Mar	454	50	11.0%
3-Mar	228	45	19.7%
6-Mar	489	117	23.9%
7-Mar	463	106	22.9%
8-Mar	432	79	18.3%
9-Mar	466	80	17.2%
10-Mar	362	42	11.6%
13-Mar	433	77	17.8%
14-Mar	502	155	30.9%
15-Mar	467	91	19.5%
16-Mar	572	141	24.7%
17-Mar	455	109	24.0%
20-Mar	496	135	27.2%
21-Mar	533	130	24.4%
22-Mar	554	166	30.0%
23-Mar	469	69	14.7%
24-Mar	467	104	22.3%
27-Mar	424	73	17.2%
28-Mar	455	63	13.8%
29-Mar	461	92	20.0%
30-Mar	573	113	19.7%
31-Mar	476	150	31.5%
Total	**10723**	**2246**	**20.9%**

135

Run chart from pass/fail data (cont'd)

136



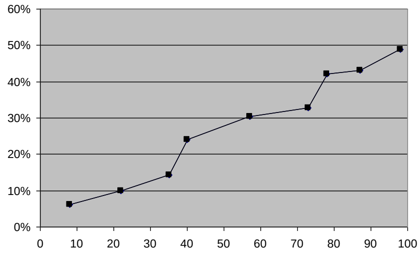
- *A very slight upward trend*
- *Probably not statistically significant*

136

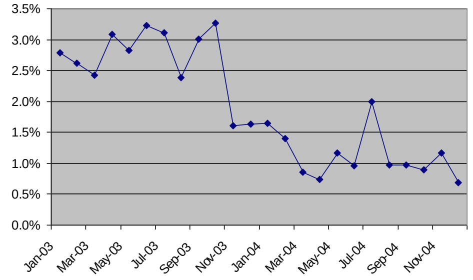
Run chart patterns

137

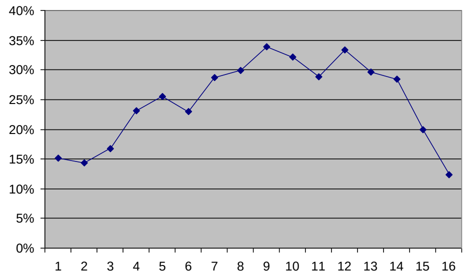
Strong upward trend



Step change



Nonlinear trend



Notes

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Pareto chart of failure modes

139

Daily tally of failure modes

	1-Mar	2-Mar	3-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	Total
Ambient too loud														17	4									
Backlight Test	3	1	1						3	4	1	3	2	1		1						3	2	
Backlight&LCDTest	14	10	8	13	12	13	5	6	12	12	12	13	3	18	17	15	16	8	13	12	12	14	17	
BatteryMeasurementCalibration	2	4	4	7	4	3	3	1	8	10	2	10	5	10	11	14	5	9	8	10	9	11	15	
Beeper not loud enough											2			3	27								1	
BeeperTest				4	3	1	3		1				1						2		1	1	2	
CommunicationsTest	3	2	7	22	11	3	19	6	6	20	7	4	1		1	3			3	5	11	11	8	
Display Test			3	1	3	4			1		1	1		6		1						2		
Event Log Size		1											2	1	1	1			1			1	1	
FinalConfig	1		2	5	2	7	7		2	2	3					2	2				4	3	1	
Operating current out of range	9	7	1	14	13	10	5		2	2	3		1	7	4			1	4		4	2	10	
OperatingCurrentTest	1	8	3	15	5	10	4	5	2	3	8	4	5	3	13	14	11	10	7	5	5	8	6	
POSTTest		1			4		3		2	3	1	1	1	3	1	3	2	2	1			2	5	
SetSerialNumber&ModelSettings				1																				
Sleep current out of range	4	2	1	14	24	21	10	6	30	70	43	90	60	41	41	92	25	55	17	15	29	37	57	
SureTempPlusTest	5	9	2	1	5	1		9		18	5	3	8	6	7	12	5	16	14	7	8	16	11	
SwitchTest	17	5	12	20	20	6	21	7	7	10	3	12	15	19	3	6	3	3	3	8	8	2	14	
RepeatabilityAccuracyTest			1					2	1	1			5			2				1	1			

Pareto chart of failure modes (cont'd)

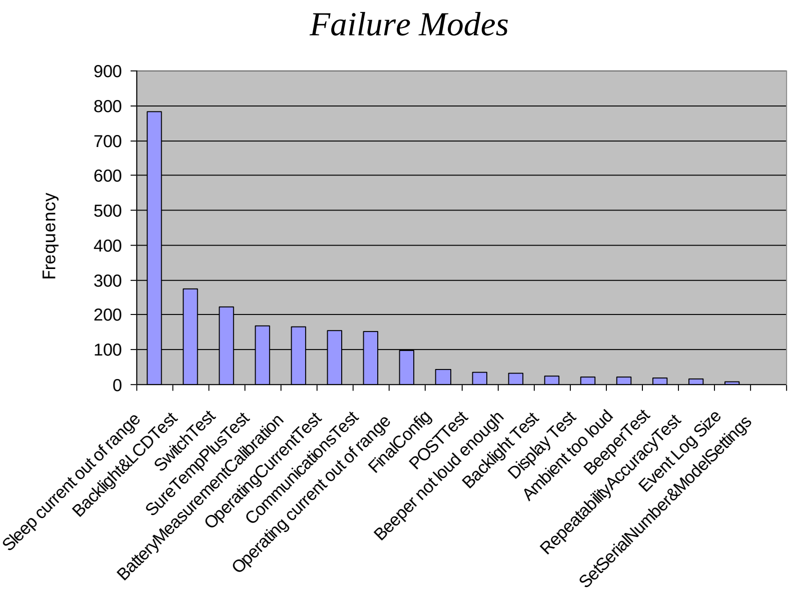
140

Failure modes with totals

	1-Mar	2-Mar	3-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	Total
Ambient too loud														17	4									21
Backlight Test	3	1	1						3	4	1	3	2	1		1						3	2	25
Backlight&LCDTest	14	10	8	13	12	13	5	6	12	12	12	13	3	18	17	15	16	8	13	12	12	14	17	275
BatteryMeasurementCalibration	2	4	4	7	4	3	3	1	8	10	2	10	5	10	11	14	5	9	8	10	9	11	15	165
Beeper not loud enough											2			3	27								1	33
BeeperTest				4	3	1	3		1				1						2		1	1	2	19
CommunicationsTest	3	2	7	22	11	3	19	6	6	20	7	4	1		1	3			3	5	11	11	8	153
Display Test			3	1	3	4			1		1	1		6		1						2		23
Event Log Size		1											2	1	1	1			1			1	1	9
FinalConfig	1		2	5	2	7	7		2	2	3					2	2				4	3	1	43
Operating current out of range	9	7	1	14	13	10	5		2	2	3		1	7	4			1	4		4	2	10	99
OperatingCurrentTest	1	8	3	15	5	10	4	5	2	3	8	4	5	3	13	14	11	10	7	5	5	8	6	155
POSTTest		1			4		3		2	3	1	1	1	3	1	3	2	2	1			2	5	35
SetSerialNumber&ModelSettings				1																				1
Sleep current out of range	4	2	1	14	24	21	10	6	30	70	43	90	60	41	41	92	25	55	17	15	29	37	57	784
SureTempPlusTest	5	9	2	1	5	1		9		18	5	3	8	6	7	12	5	16	14	7	8	16	11	168
SwitchTest	17	5	12	20	20	6	21	7	7	10	3	12	15	19	3	6	3	3	3	8	8	2	14	224
RepeatabilityAccuracyTest			1					2	1	1			5			2				1	1			14

Pareto chart of failure modes (cont'd)

141



Pareto chart interpretation

142

Which failure mode on the previous slide is the biggest problem?

Whenever possible, you should also make a Pareto of the *costs* associated with the failure modes.

Another helpful metric to associate with failure modes is *time*; for example, the amount of unplanned downtime caused by failure modes.

Stratification with pass/fail data

143

	Model 690		Model 692	
Date	Tested	Failed	Tested	Failed
1-Mar	166	12	326	47
2-Mar	347	36	107	14
3-Mar	111	21	117	24
6-Mar	289	76	200	41
7-Mar	220	62	243	44
8-Mar	330	63	102	16
9-Mar	288	56	178	24
10-Mar	283	32	79	10
13-Mar	268	44	165	33
14-Mar	158	52	344	103
15-Mar	179	36	288	55
16-Mar	329	81	243	60
17-Mar	220	37	235	72
20-Mar	280	61	216	74
21-Mar	293	57	240	73
22-Mar	273	64	281	102
23-Mar	181	21	288	48
24-Mar	198	46	269	58
27-Mar	187	31	237	42
28-Mar	219	35	236	28
29-Mar	257	60	204	32
30-Mar	414	86	159	27
31-Mar	233	59	243	91

	Model 690		Model 692	
Date	Tested	Failed	Tested	Failed
1-Mar	166	12	326	47
2-Mar	347	36	107	14
3-Mar	111	21	117	24
6-Mar	289	76	200	41
7-Mar	220	62	243	44
8-Mar	330	63	102	16
9-Mar	288	56	178	24
10-Mar	283	32	79	10
13-Mar	268	44	165	33
14-Mar	158	52	344	103
15-Mar	179	36	288	55
16-Mar	329	81	243	60
17-Mar	220	37	235	72
20-Mar	280	61	216	74
21-Mar	293	57	240	73
22-Mar	273	64	281	102
23-Mar	181	21	288	48
24-Mar	198	46	269	58
27-Mar	187	31	237	42
28-Mar	219	35	236	28
29-Mar	257	60	204	32
30-Mar	414	86	159	27
31-Mar	233	59	243	91
	5723	**1128**	**5000**	**1118**
		19.7%		**22.4%**

- Model 692 has a higher failure rate than 690
- There are larger differences among the 3 testers (see next page)

Stratification with pass/fail data (cont'd)

144

	Tester 1		Tester 2		Tester 3	
Date	Tested	Failed	Tested	Failed	Tested	Failed
1-Mar	142	13	183	34	167	12
2-Mar	155	20	168	12	131	18
3-Mar	87	10	73	17	68	18
6-Mar	184	42	153	33	152	42
7-Mar	159	25	164	29	140	52
8-Mar	196	37	177	29	59	13
9-Mar	137	12	203	33	126	35
10-Mar	132	15	170	22	60	5
13-Mar	114	22	189	25	130	30
14-Mar	166	54	198	65	138	36
15-Mar	148	32	176	35	143	24
16-Mar	185	50	221	48	166	43
17-Mar	181	54	115	26	159	29
20-Mar	162	33	148	39	186	63
21-Mar	165	25	187	41	181	64
22-Mar	198	41	176	49	180	76
23-Mar	181	21	146	21	142	27
24-Mar	199	45	145	25	123	34
27-Mar	192	31	106	21	126	21
28-Mar	167	33	139	10	149	20
29-Mar	113	28	189	37	159	27
30-Mar	213	52	199	33	161	28
31-Mar	175	37	133	24	168	89

	Tester 1		Tester 2		Tester 3	
Date	Tested	Failed	Tested	Failed	Tested	Failed
1-Mar	142	13	183	34	167	12
2-Mar	155	20	168	12	131	18
3-Mar	87	10	73	17	68	18
6-Mar	184	42	153	33	152	42
7-Mar	159	25	164	29	140	52
8-Mar	196	37	177	29	59	13
9-Mar	137	12	203	33	126	35
10-Mar	132	15	170	22	60	5
13-Mar	114	22	189	25	130	30
14-Mar	166	54	198	65	138	36
15-Mar	148	32	176	35	143	24
16-Mar	185	50	221	48	166	43
17-Mar	181	54	115	26	159	29
20-Mar	162	33	148	39	186	63
21-Mar	165	25	187	41	181	64
22-Mar	198	41	176	49	180	76
23-Mar	181	21	146	21	142	27
24-Mar	199	45	145	25	123	34
27-Mar	192	31	106	21	126	21
28-Mar	167	33	139	10	149	20
29-Mar	113	28	189	37	159	27
30-Mar	213	52	199	33	161	28
31-Mar	175	37	133	24	168	89
	3751	**732**	**3758**	**708**	**3214**	**806**
		19.5%		**18.8%**		**25.1%**

Run chart from quantitative data

145

Data values for 3 days

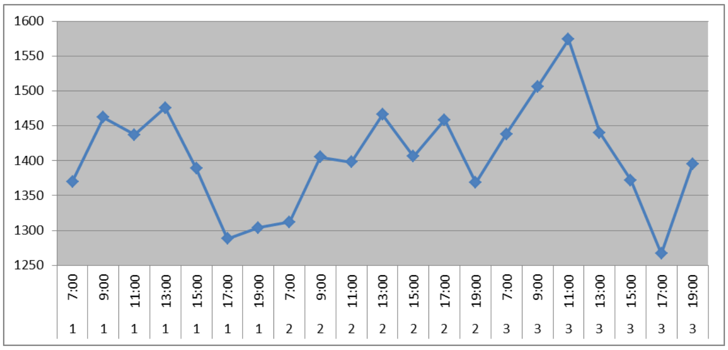
		Day		
		1	**2**	**3**
Time of day	**7:00**	1370	1312	1438
	9:00	1462	1405	1506
	11:00	1437	1398	1574
	13:00	1476	1466	1440
	15:00	1389	1406	1372
	17:00	1288	1459	1267
	19:00	1304	1369	1395

145

Run chart from quantitative data (cont'd)

146

Data values by hour for 3 days



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Stratification with quantitative data

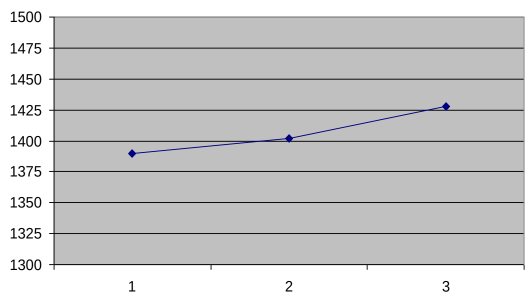
147

		Day			
		1	2	3	Avgs.
Time of day	7:00	1370	1312	1438	1373.3
	9:00	1462	1405	1506	1457.7
	11:00	1437	1398	1574	1469.7
	13:00	1476	1466	1440	1460.7
	15:00	1389	1406	1372	1389.0
	17:00	1288	1459	1267	1337.8
	19:00	1304	1369	1395	1355.8
	Avgs.	1389.4	1402.0	1427.4	

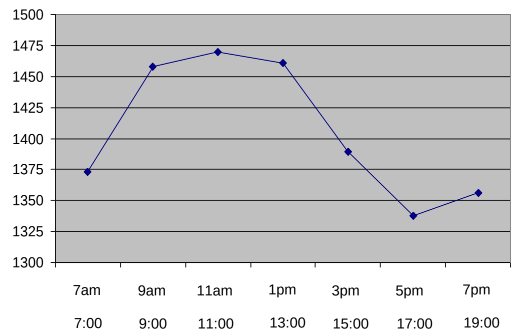
147

Stratification with quantitative data (cont'd)

148



Slight upward trend in the daily averages



Distinct pattern in the averages by time of day

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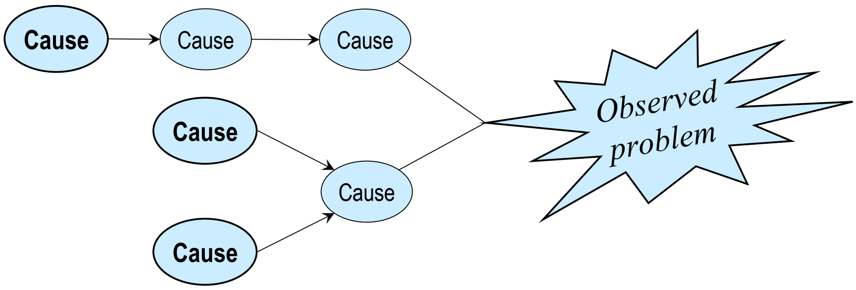
Root cause analysis

149

- Mapping and observing the in scope workflow usually reveals opportunities for improvement
- These are starting points for root cause analysis



- Data analysis often produces additional starting points

Root cause analysis

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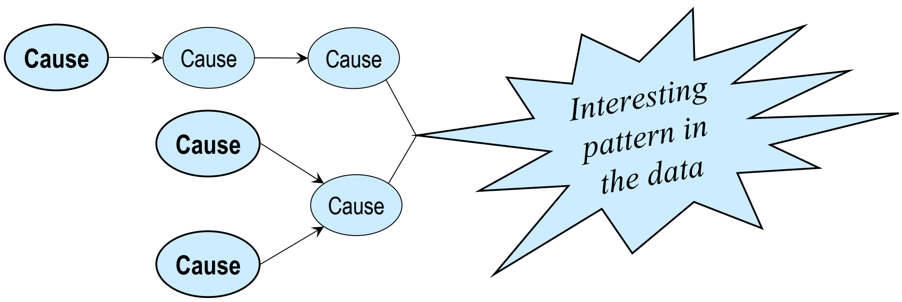

- "Why is the failure rate for Tester 3 higher than for Testers 1 and 2?"
- "Why is the resistivity higher on Tuesdays, Wednesdays and Thursdays than on the other days of the week?"

Getting to root cause — "Five Whys"

151

- For each problem or observation, ask a series of questions
- The purpose of each question should be to take you closer to the root cause of the problem or observation
- The questions do not have to start with "why"
- Put some thought into how you phrase your questions — you don't want to annoy or antagonize the person you are interviewing
- Bring the conversation back to the root cause path if it wanders into "solution space" or "who's to blame"
- Once you have the root cause, the solution is not far away

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Exercise 12: Five Whys

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- Your instructor will now lead you through a verbal exercise to practice the Five Whys technique.
- The instructor will make the opening statements and answer the questions.
- Class members will ask the questions.
- The instructor will indicate which class member is to ask the next question.

Please close your workbook now!

152

Exercise 12: Five Whys for scrap in the Coiling department

153

Opening statement:	There's too much scrap in the Coiling Department!
What kinds of defects are causing the scrap?	The vast majority are due to bad welds.
Why do we have so many bad welds?	The welders aren't very good.
Why aren't they very good?	It's an entry level position, and they don't get much training.
Why aren't they given more training?	I don't know. I guess there isn't enough time. This is the way we've always done it.
Why don't you use certified welders?	Are you kidding? We would have to pay them too much.

153

Exercise 12: Five Whys for scrap (cont'd)

154

Don't your welders get better as they become more experienced?	No, because they don't stay in this department long enough for that to happen.
Why do they leave this department so soon?	There's another department where welders are used. As soon as there's an opening over there, everybody here applies for it.
Why are they so eager to work in the other department?	We have the highest accident rate in the company. The working conditions in the other department are much better. Also, they get paid a dollar an hour more than here.
What is the annual cost of scrap in the Coiling Department?	I don't know, but every day they fill a large dumpster with scrap metal.

154

Affinity Analysis of potential causes

155

- A team may accumulate a long list of potential causes of the problem, developed over the course of the project
- Usually, some of these are redundant or closely related
- Also, some of the items on the list may have a cause-and-effect linkage with each other
- The objective of affinity analysis is to reduce an initial list down to a relatively short final list of distinct root causes
- These will be the basis for developing the solution ideas that define the future state

Affinity analysis: general process

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1. If there is not a list to start with, participants brainstorm potential causes and write them individually on separate sticky notes (actual or digital). This process occurs in silence. (Why?)
2. Continuing in silence, the causes are placed on a table, wall or digital whiteboard.
3. As each new potential cause is revealed, the team groups it with redundant or closely related potential causes already revealed, or
4. A cause can be placed by itself to start a new group.
5. Once ideas are grouped, the silence is broken and the team discusses how to convert the grouped ideas into actionable categories, items, investigations, etc.

Affinity analysis example – step 1: brainstorm

157

Root cause observations for "mistakes and delays"

- Equipment can't hold tolerances
- Too much moving back and forth
- Wrong kind material ordered
- People don't follow work instructions
- Too much unplanned downtime
- Wrong kind material delivered
- Equipment unreliable
- Material out of spec
- Equipment not available
- Poor work area layout
- Not enough machines to meet demand
- Material ordered late
- Wrong quantity ordered
- Equipment hard to use
- Run out of material during job
- Machines are out of sequence
- Equipment outdated
- Wrong type material delivered
- Material delivered late
- Lack of training on equipment
- Work instructions out of date
- Material not available
- Work instructions confusing
- Storage area far from work area
- Machines breaking down
- Raw material not ordered
- Work instructions wrong
- Wrong quantity delivered
- Poor quality material
- Wrong type material ordered

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Affinity example – step 2: initial groups

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- Equipment can't hold tolerances
- Equipment unreliable
- Equipment hard to use
- Equipment outdated
- Equipment not available
- Too much unplanned downtime
- Not enough machines to meet demand
- Machines breaking down

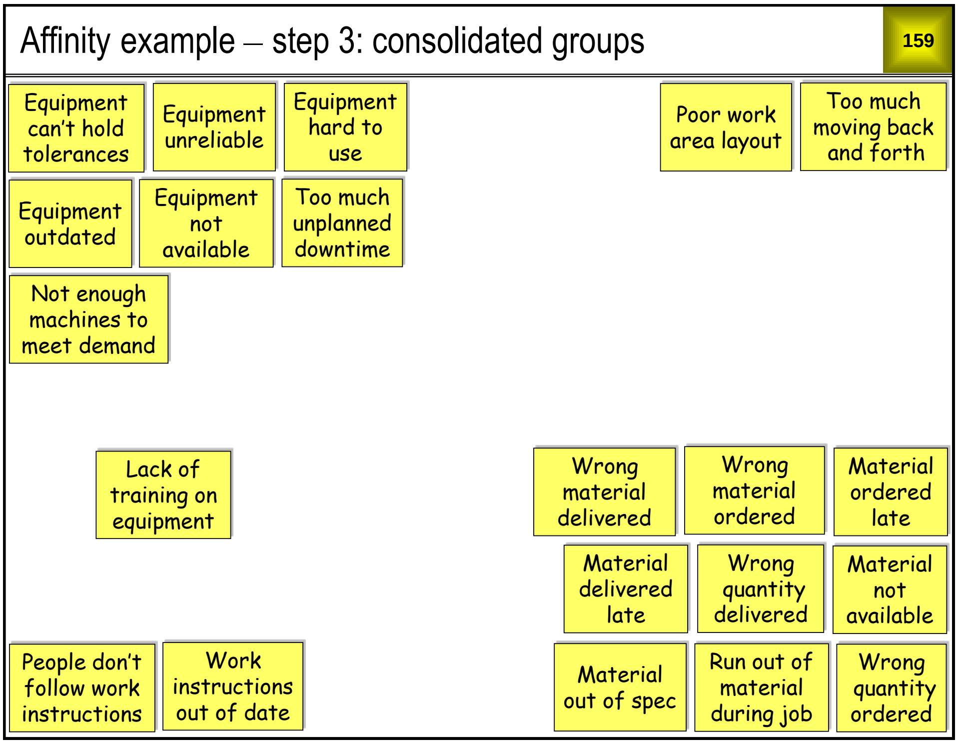
- Machines are out of sequence
- Too much moving back and forth
- Poor work area layout
- Storage area far from work area

- Lack of training on equipment

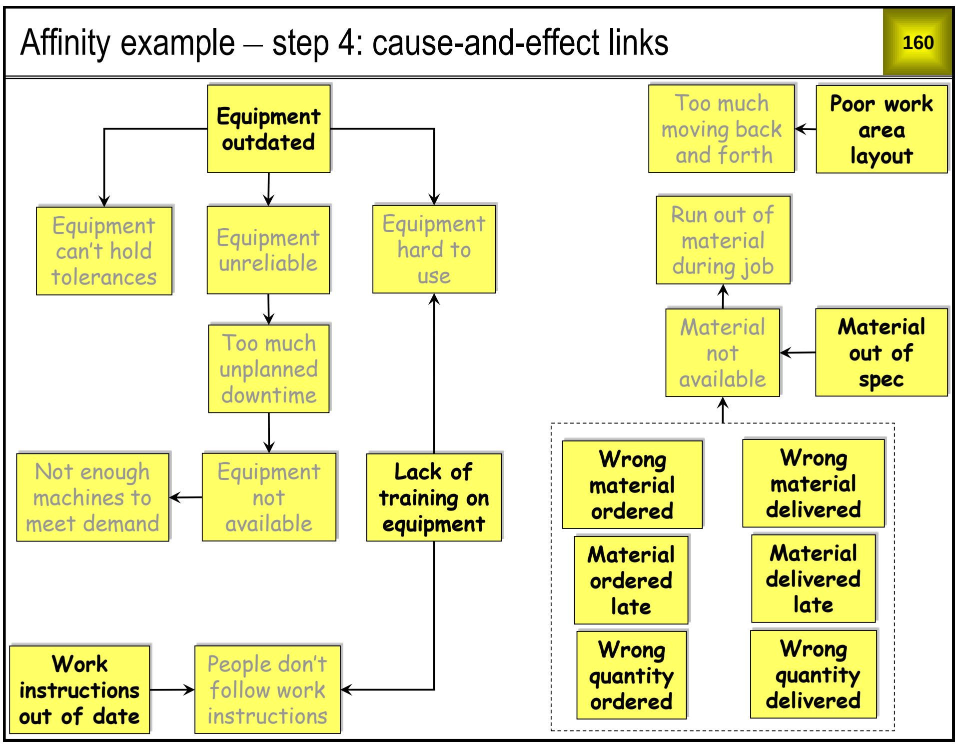
- Material delivered late
- Wrong type material delivered
- Wrong kind material delivered
- Wrong type material ordered
- Wrong kind material ordered
- Material ordered late
- Poor quality material
- Material out of spec
- Wrong quantity delivered
- Material not available
- Raw material not ordered
- Run out of material during job
- Wrong quantity ordered

- People don't follow work instructions
- Work instructions wrong
- Work instructions confusing
- Work instructions out of date

158


Affinity example – step 3: consolidated groups
159
Equipment can't hold tolerances
Equipment unreliable
Equipment hard to use
Poor work area layout
Too much moving back and forth
Equipment outdated
Equipment not available
Too much unplanned downtime
Not enough machines to meet demand
Lack of training on equipment
Wrong material delivered
Wrong material ordered
Material ordered late
Material delivered late
Wrong quantity delivered
Material not available
People don't follow work instructions
Work instructions out of date
Material out of spec
Run out of material during job
Wrong quantity ordered

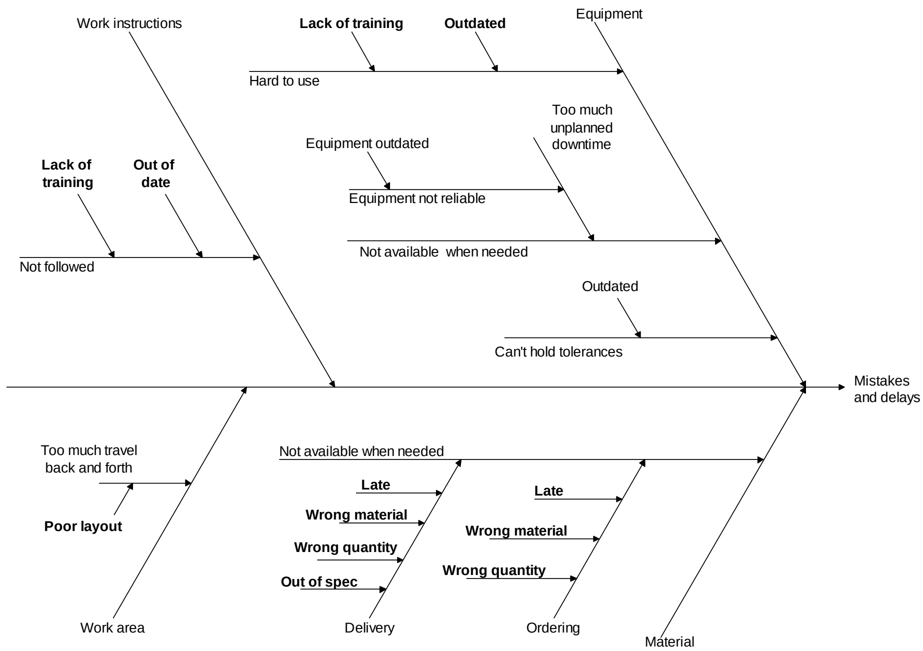
159


Affinity example – step 4: cause-and-effect links
160
Equipment outdated
Too much moving back and forth
Poor work area layout
Equipment can't hold tolerances
Equipment unreliable
Equipment hard to use
Run out of material during job
Too much unplanned downtime
Material not available
Material out of spec
Not enough machines to meet demand
Equipment not available
Lack of training on equipment
Wrong material ordered
Wrong material delivered
Material ordered late
Material delivered late
Wrong quantity ordered
Wrong quantity delivered
Work instructions out of date
People don't follow work instructions

160

Fishbone diagram of same information

161



Fishbone (cont'd)

162

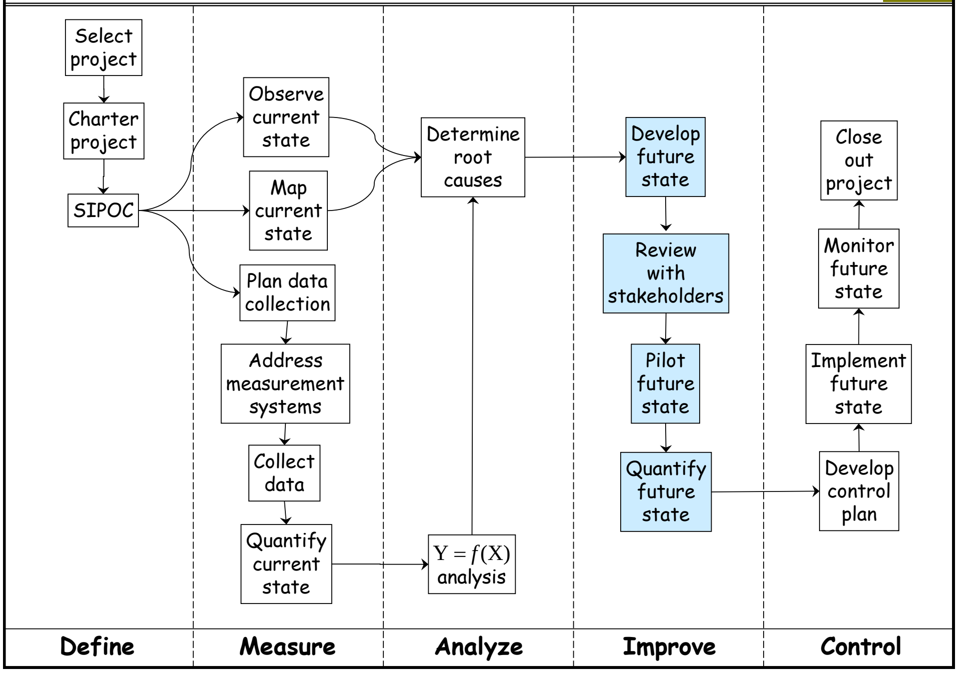
The team process usually associated with a fishbone (aka Cause and Effect Diagram) starts with broad categories (Man, Machine, Materials, Methods, Measurement, Environment) that are used as the main branches. The 5 whys process is then used to add smaller branches representing causes. The root causes are on the smallest branches.

A fishbone is a good way to document this Affinity process after it is completed, but it can be inefficient to try to develop the fishbone during the process if team members waste time worrying about the structure of the diagram, which can become complex and difficult to modify as the process unfolds.

Affinity analysis is an open, flexible process. It is easy to add new things as they arise and move things around as needed. The broad categories of the fishbone diagram (the 5 M's and an E) should be brought in only at the end of the process to make sure nothing has been overlooked.

8 Improve Phase of LSS

163



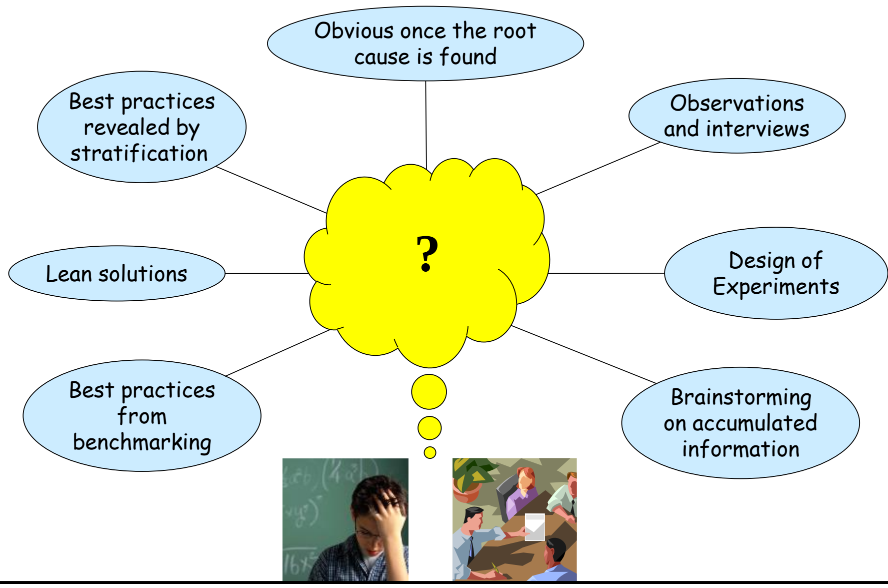
Topics

164

- Developing solutions
- Prioritizing solutions
- Piloting the future state

Developing solutions

Solution ideas come from many sources



Solution ideas often come directly from root causes

Root causes of "mistakes and delays"	*Solution ideas*
Equipment outdated	Replace equipment
Poor work area layout	Redesign work area layout
Material not ordered	
Wrong material ordered	Project on ordering process
Wrong quantity ordered	
Material delivered late	
Wrong material delivered	Project on supplier order fulfillment
Wrong quantity delivered	
Material out of spec	Project on supplier quality
Work instructions out of date	Update work instructions
Lack of training on equipment	Implement document control system
	Training on document control system

Brainstorming

167

- A structured team activity for generating ideas
- Can produce many ideas in a short period of time
- Separates *generation* of ideas from *organization* and *assessment* of ideas
- In the traditional brainstorming process, ideas are expressed verbally
- Often, it is better to have people write their ideas on pieces of paper (why?)

167

Brainstorming "rules of engagement"

168

Do	*Do not*
• Allow individuals to complete their thoughts • Build on existing ideas or ideas of others • State ideas as concisely as possible • State and accept "ridiculous" ideas • Strive for quantity	• Discuss or criticize ideas during the process • Paraphrase an individual's idea when scribing • Dominate the session • Allow someone else to dominate the session • Organize, categorize or evaluate ideas during the process

168

Benchmarking

169

- Compare your performance with that of other organizations
- Identify best practices
- Borrow good ideas
- Methods
  - ✓ Mail surveys
  - ✓ Databases
  - ✓ Phone surveys
  - ✓ Consortia
  - ✓ Personal interviews
  - ✓ Publications
  - ✓ Trade magazines
  - ✓ Company tours
  - ✓ Professional associates
  - ✓ Trade meetings
  - ✓ Conversations

Notes

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Prioritizing solutions

171

- Multi-voting (N/3 technique)
- Impact - Feasibility Analysis

171

Multi-voting

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- A team has developed a list of ideas
- They have clarified meanings and eliminated duplicates
- Each team member gets N/3 votes*, where N is the number of items on the list
- Team decides whether or not to allow voting more than once for one item
- Each team member assigns their allotted votes by placing marks beside items on the list

	IMPROVE INFORMATION FLOW
	VERIFY INSURANCE AT SCHEDULING
	STAFF TO DEMAND, NOT CAPACITY
	IMPROVE IMPORT OF HOSPITAL INFORMATION
	REDUCE PATIENT PHONE WAIT TIMES
	ENABLE E-RECEIPT OF DEMOS
	STANDARDIZE TRAINING FOR NEW HIRES
	STANDARDIZE ORAL CONTRAST FOR CT
	BALANCE PATIENT DISTRIBUTION AMONG SITES
	REDUCE REPORT TURNAROUND TIME

*Rounded to the nearest whole number

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Multi-voting example

173

10 items, 15 people, 3 votes each

///// /	IMPROVE INFORMATION FLOW
///// ///// ////	VERIFY INSURANCE AT SCHEDULING
///	STAFF TO DEMAND, NOT CAPACITY
////	IMPROVE IMPORT OF HOSPITAL INFORMATION
	REDUCE PATIENT PHONE WAIT TIMES
	ENABLE E-RECEIPT OF DEMOS
///	STANDARDIZE TRAINING FOR NEW HIRES
/	STANDARDIZE ORAL CONTRAST FOR CT
///// /	BALANCE PATIENT DISTRIBUTION AMONG SITES
/	REDUCE REPORT TURNAROUND TIME

173

Multi-voting example

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How each person voted

	PAUL	CHRIS	TOM	DENNIS	JENNIFER	MICHELLE	ALICE	ERIN	DOLORES	SALLY	SHANNON	PATTY	JUDY	NICOLE	BRIAN	Total
IMPROVE INFORMATION FLOW		1	1	1			1		1						1	6
VERIFY INSURANCE AT SCHEDULING	2	1	2	1		1	1	1	1	1	1	1	1			14
STAFF TO DEMAND, NOT CAPACITY					1									1	1	3
IMPROVE IMPORT OF HOSPITAL INFORMATION								1		1	1	1				4
REDUCE PATIENT PHONE WAIT TIMES	1			1	1	1		1					1	1		7
ENABLE E-RECEIPT OF DEMOS																0
STANDARDIZE TRAINING FOR NEW HIRES							1			1	1					3
STANDARDIZE ORAL CONTRAST FOR CT														1		1
BALANCE PATIENT DISTRIBUTION AMONG SITES		1			1	1			1			1	1			6
REDUCE REPORT TURNAROUND TIME															1	1
																0
																0

Putting 2 votes on one item was allowed, but not 3

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Impact - Feasibility analysis

175

For a given team with a specific list of solution ideas, ranking each solution in terms of its potential impact on the identified root cause(s) usually gives a different result than multi-voting. The impact prioritization method forces us to think about the *reasons* certain items should be given higher priority than others. Using a method that considers impact is superior to multi-voting.

Even better is to include an evaluation of the feasibility of solutions.

Ultimately best is to apply weights to root causes:

- weights are determined using criteria such as frequency of occurrence, severity, degree of correlation to the problem effect, etc.);
- solutions that impact higher-weighted root causes will rank higher than solutions that only impact lower-weighted root causes.

Of course, multi-voting is quicker and easier. The decision as to which method to use is a judgment the team leader or facilitator must make.

To get the best of both worlds, multi-voting can be an efficient way to narrow down a long list of items for further prioritization.

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Impact - Feasibility analysis for "mistakes and delays"

176

Root Causes	Relative weights		Feasibility metrics	Relative weights
Equipment outdated	147		Inexpensive implementation	2
Poor work area layout	147		Rapid implementation	1
Material not ordered	63		Rapid accrual of benefits	2
Wrong material ordered	63		Resources available	2
Wrong quantity ordered	27		No resistance to implementation	1
Material delivered late	147		No chance of bad side effects	1
Wrong material delivered	63			
Wrong quantity delivered	27			
Poor quality material	63			
Work Instructions out of date	147			
Lack of training on equipment	147			

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Impact ranking for “mistakes and delays”

Root Causes / Items to be ranked	Equipment outdated	Poor work area layout	Material not ordered	Wrong material ordered	Wrong quantity ordered	Material delivered late	Wrong material delivered	Wrong quantity delivered	Poor quality material	Work instructions out of date	Lack of training on equipment	0	0	0	0	Overall rankings
Relative weights	147	147	63	63	27	147	63	27	63	147	147	0	0	0	0	
Replace equipment																0
Redesign work area layout																0
Project on ordering process																0
Project on supplier order fulfillment																0
Project on supplier quality																0
Update work instructions																0
Implement document control system																0
Training on document control system																0
																0

Degree of positive impact of each item with each metric: None (blank) Low (L) Medium (M) High (H)

The solutions are listed on the left. Each solution is rated for its impact on each root cause.

It’s best to work one row at a time, evaluating a solution across all root causes.

Example: Impact ranking for “mistakes and delays”

Root Causes / Items to be ranked	Equipment out dated	Poor work area layout	Material not ordered	Wrong material ordered	Wrong quantity ordered	Material delivered late	Wrong material delivered	Wrong quantity delivered	Poor quality material	Work Instructions out of date	Lack of training on equipment	0	0	0	0	Overall rankings
Relative weights	147	147	63	63	27	147	63	27	63	147	147	0	0	0	0	
Replace equipment	H	L														1470
Redesign work area layout		H														1323
Project on ordering process			H	H	H											1377
Project on supplier order fulfillment						H	H	H								2133
Project on supplier quality									H							567
Update work instructions										H	L					1470
Implement document control system										H	L					1470
Training on document control system										M	H					1764
																0

Degree of positive impact of each item with each metric: None (blank) Low (L) Medium (M) High (H)

A number is assigned to each rank for calculation purposes.
It is customary to use a non-linear scale:

Low = 1
Medium = 3
High = 9

Overall rank for each solution = the sum of (solution rank x root cause weight).

Feasibility ranking for “mistakes and delays”

179

Feasibility metrics	Inexpensive implementation	Rapid implementation	Rapid accrual of benefits	Resources available	No resistance to implementation	No chance of bad side effects	0	0	0	0	0	0	0	0	0	Overall rankings
Relative weights	2	1	2	2	1	1	0	0	0	0	0	0	0	0	0	
Items to be ranked																
Replace equipment																0
Redesign work area layout																0
Project on ordering process																0
Project on supplier order fulfillment																0
Project on supplier quality																0
Update work instructions																0
Implement document control system																0
Training on document control system																0
0																0

Degree of positive correlation of each item with each metric: Low (L) Medium (M) High (H)

The solutions are listed on the left. Each solution is rated against each feasibility metric.

It’s best to work one column at a time, evaluating a feasibility metric down all solutions.

A “High” rank means the feasibility metric will be a “true” statement for the solution.

In the example above, an “H” for “inexpensive implementation” would mean the proposed solution will be inexpensive.

An “L” would mean the statement is “false,” i.e., the solution will be expensive (it cannot *feasibly* be estimated to be inexpensive).

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Example: Feasibility ranking for “mistakes and delays”

180

Feasibility metrics	Inexpensive implementation	Rapid implementation	Rapid accrual of benefits	Resources available	No resistance to implementation	No chance of bad side effects	0	0	0	0	0	0	0	0	0	Overall rankings
Relative weights	2	1	2	2	1	1	0	0	0	0	0	0	0	0	0	
Items to be ranked																
Replace equipment	L	M	H	H	H	M										53
Redesign work area layout	M	H	H	H	H	M										63
Project on ordering process	H	L	M	M	M	H										43
Project on supplier order fulfillment	M	L	M	M	L	H										29
Project on supplier quality	M	L	M	M	L	H										29
Update work instructions	H	H	H	H	H	H										81
Implement document control system	M	M	H	H	H	H										63
Training on document control system	M	M	M	H	H	H										51
0																0

Degree of positive correlation of each item with each metric: Low (L) Medium (M) High (H)

The same non-linear scale is used for Feasibility calculations:

Low = 1

Medium = 3

High = 9

Overall rank for each solution = the sum of (solution rank x root cause weight).

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Impact - Feasibility analysis plot

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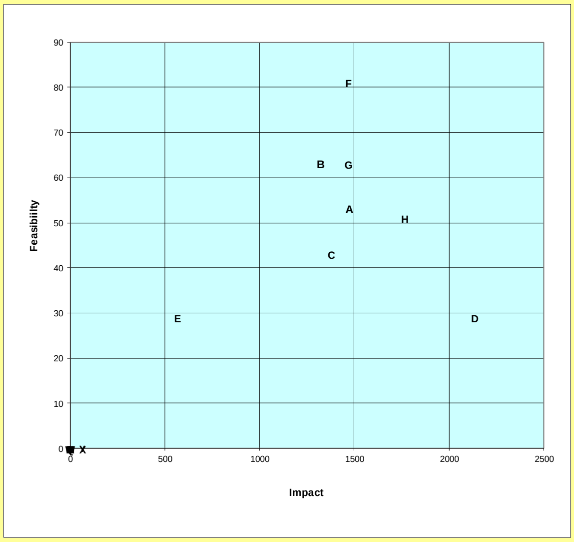
Items to be ranked	Tag	Impact	Feasibility
Replace equipment	A	1470	53
Redesign work area layout	B	1323	63
Project on ordering process	C	1377	43
Project on supplier order fulfillment	D	2133	29
Project on supplier quality	E	567	29
Update work instructions	F	1470	81
Implement document control system	G	1470	63
Training on document control system	H	1764	51
0	I	0	0
0	J	0	0
0	K	0	0
0	L	0	0
0	M	0	0
0	N	0	0
0	O	0	0
0	P	0	0
0	Q	0	0
0	R	0	0
0	S	0	0
0	T	0	0
0	U	0	0
0	V	0	0
0	W	0	0
0	X	0	0
0	Y	0	0



Realities of prioritizing

182

In a perfect world, the highest priority would be to implement the solution with highest impact-feasibility score. The second highest priority would be to implement the solution with the second highest score, and so on.

In reality, the solution rankings must be viewed holistically in the context of the organization and its current environment. Think of the Impact-Feasibility plot as an aid to discussion in determining how many solutions to implement at a given time, and in what order.

It may be helpful to implement a lower impact but highly feasible solution as a “demonstration” project to build support for LSS efforts.

Reviewing the proposed solution with stakeholders

183

- Create documents describing the proposed changes
- Should include the analysis results and other findings that support the changes
- Present the proposed changes to stakeholders
- Encourage them to express any questions or concerns they may have
- Revise your proposal as needed
- Plan your future state pilot study in collaboration with process owners and stakeholders

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Piloting the future state

184

- Pilot = small scale implementation under close observation
- Scope should be limited*
- Time period should be relatively short
- Test and evaluate improvement objectives
- Reality check prior to full scale implementation

*We try to scope improvement projects into manageable chunks. Because of this, the pilot scope may sometimes be the same as the project scope. In such cases, the only new issue for defining the pilot is to determine the duration.

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Piloting checklist

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- ❑ What is the scope? (Location, work area, products, . . .)
- ❑ What is the duration?
- ❑ Who are the participants? (Process owner, process participants, stakeholders, team members…)
- ❑ What data is to be collected? (Y variables and project metrics must be same as in Define and Measure phases.)
- ❑ Have we communicated plans to all concerned parties?

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Analyzing pilot results

186

- Collect observations — what worked, what didn't
- Calculate project metrics based on pilot data
- Evaluate performance relative to project goals
- Compare "before" metrics to "after" metrics

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Example: project to reduce lead time and improve quality

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Comparison of current state and future state metrics

	Current state	
Transaction	Lead time (days)	Complete & accurate
1	10	Yes
2	4	No
3	13	No
4	2	Yes
5	6	No
6	11	No
7	6	No
8	5	Yes
9	27	No
10	19	Yes
11	4	Yes
12	17	No
13	9	No
14	11	No
15	6	Yes
16	5	Yes
17	12	Yes
18	8	Yes
19	1	Yes
20	12	No
21	2	Yes
22	2	Yes
23	7	No
24	15	No
25	21	Yes

	Future state	
Transaction	Lead time (days)	Complete & accurate
1	4	Yes
2	2	Yes
3	4	Yes
4	8	No
5	3	Yes
6	5	Yes
7	12	No
8	4	Yes
9	10	Yes
10	2	Yes
11	3	Yes
12	4	Yes
13	3	Yes
14	3	Yes
15	4	Yes
16	10	Yes
17	9	Yes
18	3	Yes
19	5	Yes
20	4	Yes
21	2	Yes
22	5	Yes
23	3	Yes

	Current state	Future state
Avg. lead time	9.4	4.9
% Lead times > 10	40.0	4.3
% C & A	52.0	91.3

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Notes

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9 Lean Solutions

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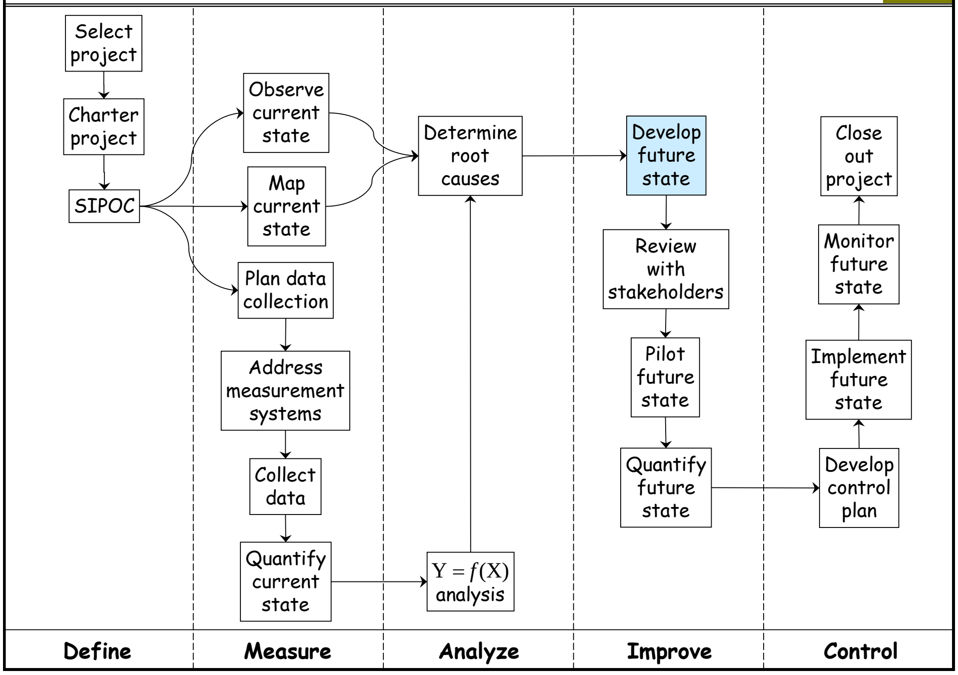

Common Lean solutions

190

Stop & fix

Pull systems

Standardization

Setup reduction

Mistake proofing

Reduce batch sizes

Value stream teams

Work balancing

Visual management

5S: Sort, Stow, Sweep, Standardize, Sustain

⋮

Examples of mistake-proofing

191

- Designing connecting cables and ports so that a cable cannot be plugged into the wrong port
- Programming software so that the user cannot proceed unless necessary information is filled in
- Auto fill of previously entered information on electronic forms
- Pull down menus in computer programs — especially for data entry
- Using feedback control systems and alarms on equipment
- Fixturing to prevent incorrect placement and hold things in place

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Notes

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Reduce batch sizes (keep the work moving)

193

Don't do things in batches.
The ideal is to do one thing at a time.
Come as close to this as you can.

- Wait a minute — batching is supposed to be "efficient"
- Maybe, but here are some problems with batching:
  - ✓ One mistake can ruin a whole batch before the problem is detected
  - ✓ A customer who wants just one item has to wait for a whole batch to be completed
  - ✓ Items accumulate until the batch quantity is reached — wastes space, creates opportunities for defects

193

Reduce batch sizes (cont'd)

194

Of course, there can be a legitimate problem with reducing batch sizes: it increases the number of setups or changeovers.

Fortunately, this is a problem for which Lean has excellent solutions. Lean projects have reduced changeover times by 80% or more.

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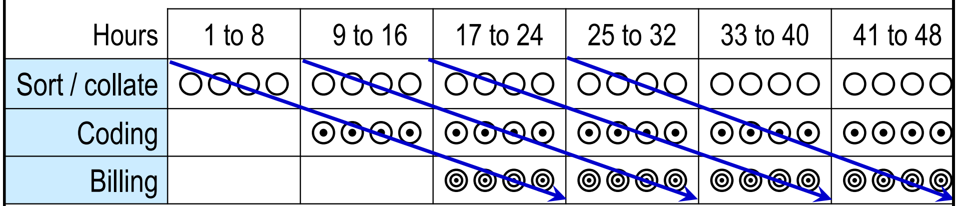
Current state: daily batching

195

3 operations
2 hours per transaction per operation

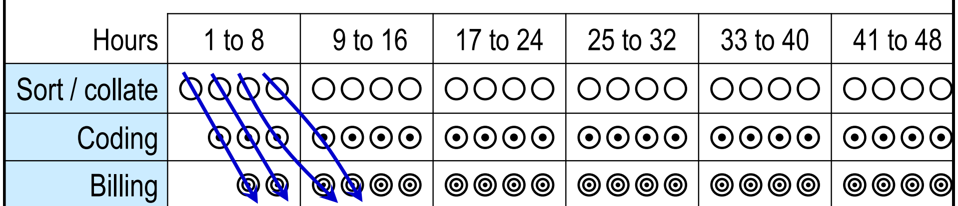


Lead time = 24 hours (3 days)

Future state: continuous flow

196

3 operations
2 hours per transaction per operation

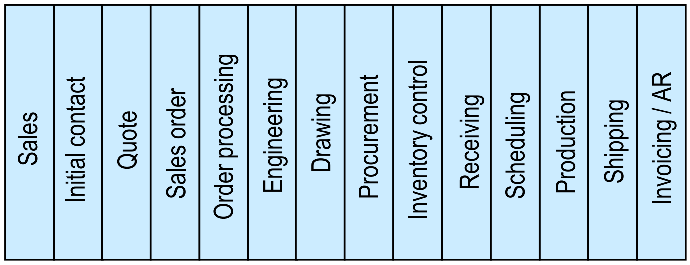


Lead time = 6 hours (less than one day)

Reducing batch size reduces cycle time!

Organizing by departments

197



- Departmental boundaries create “silos”
- Often, no single entity has overall responsibility for customer satisfaction
- Vestige of industrial revolution — need for specialization
- Hand offs between silos are opportunities for poor communication and lack of coordination

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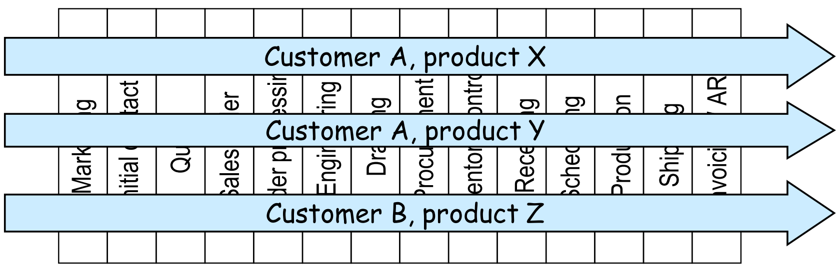
Organizing by value stream

198



"We want to not only show respect to our people, the same way we want to show respect to everyone we meet in life, we also want to respect their humanity, what it is that makes us human, which is our ability to think and feel – we have to respect that humanity in the way we design the work, so that the work enables their very human characteristics to flourish."

— Fuji Cho, as quoted in John Shook’s “Managing to Learn”

Mr. Fuji Cho has held many leadership positions at Toyota, including President and is currently an Honorary Chairman of the company. He was explaining in this quote why they did not call their operating philosophy the “Toyota Production Method” but the "Respect for Humanity" system.

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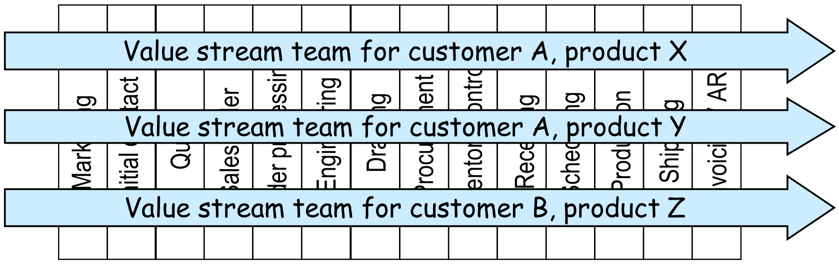
Organizing by value stream (cont'd)

199



- Responsible for entire value stream for a product/service "family"
- Physical co–location is ideal (work cells)
- Alternative: "value stream team"
- Stand-up meetings: every day, shift, or other frequent interval
- Alternative: virtual meetings

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Notes

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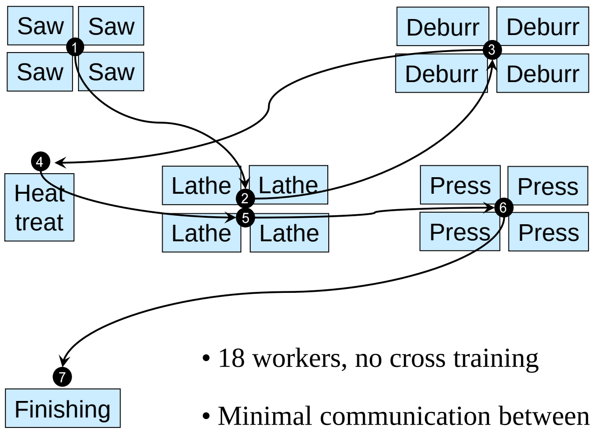
Manufacturing operation in silos

201

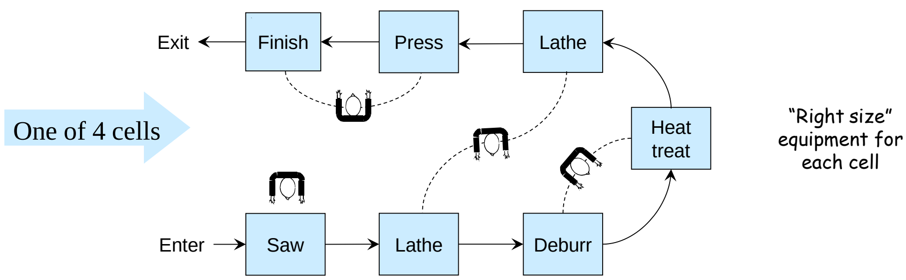


- 18 workers, no cross training
- Minimal communication between silos
- Each silo handles all products
- Silos produce as much as possible, all the time (push system)
- WIP moves between silos in large batches → long lead time

201

Manufacturing operation in U-shaped work cells

202

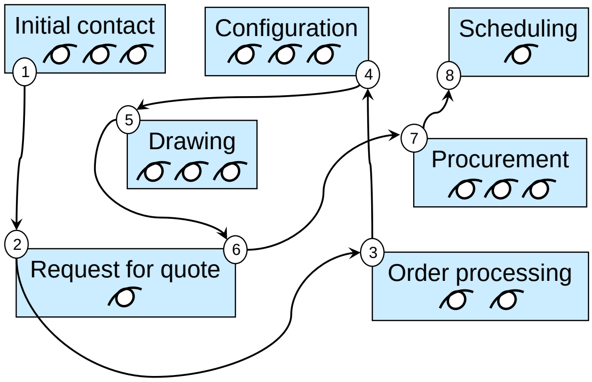


- Each cell handles all operations for one product family, and produces just what is needed to meet current demand (pull system)
- Continuous flow → minimal WIP → short lead time
- Rapid response to workflow or quality problems
- 16 workers instead of 18 — what happens to the other 2?

202

Transactional process in silos

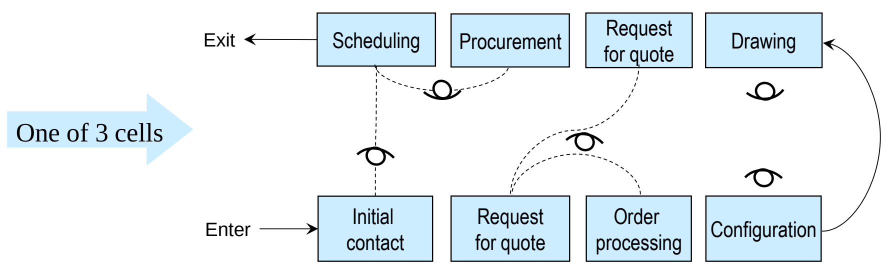
203



- 16 workers, no cross training
- Each silo handles all transactions
- Minimal communication between silos
- Lots of do overs (not shown in diagram)
- Lots of WIP → long turnaround time

Transactional process in U-shaped work cells

204

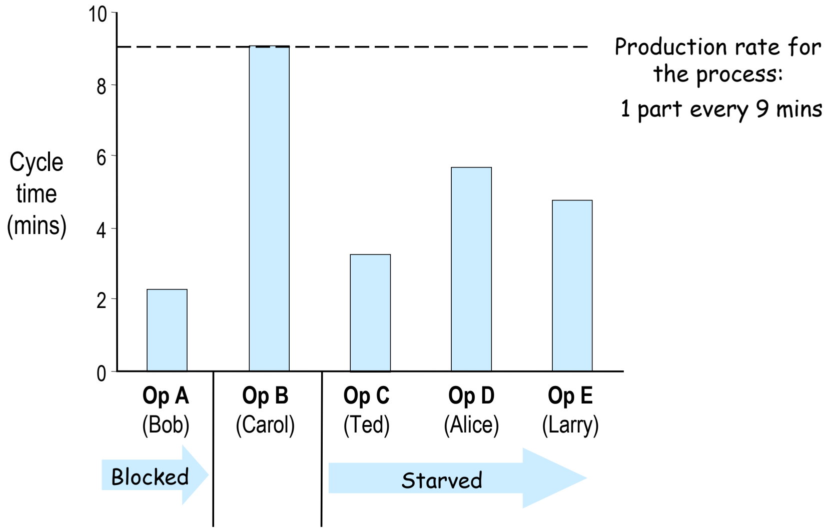


- Each cell handles all steps for one transaction family
- Continuous flow → minimal WIP→ short turnaround time
- Rapid response to errors or workflow problems
- 15 workers instead of 16 — what happens to the other one?

Work balancing

205

Production rate for a process = production rate for the *slowest* operation



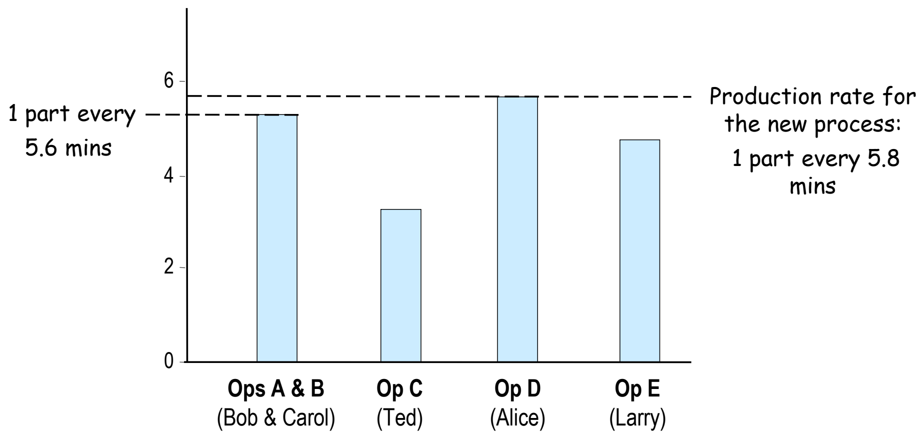
Improving work balance by cross training

206

- Teach Bob how to do B, teach Carol how to do A, have them both do A & B
- Touch time for A & B = 2.2 + 9.0 = 11.2
- Together, Bob and Carol can produce 1 part every 5.6 minutes (2 parts every 11.2 minutes)
- Where is the next best opportunity for cross training?

Cross training (cont'd)

207



Lean workshop

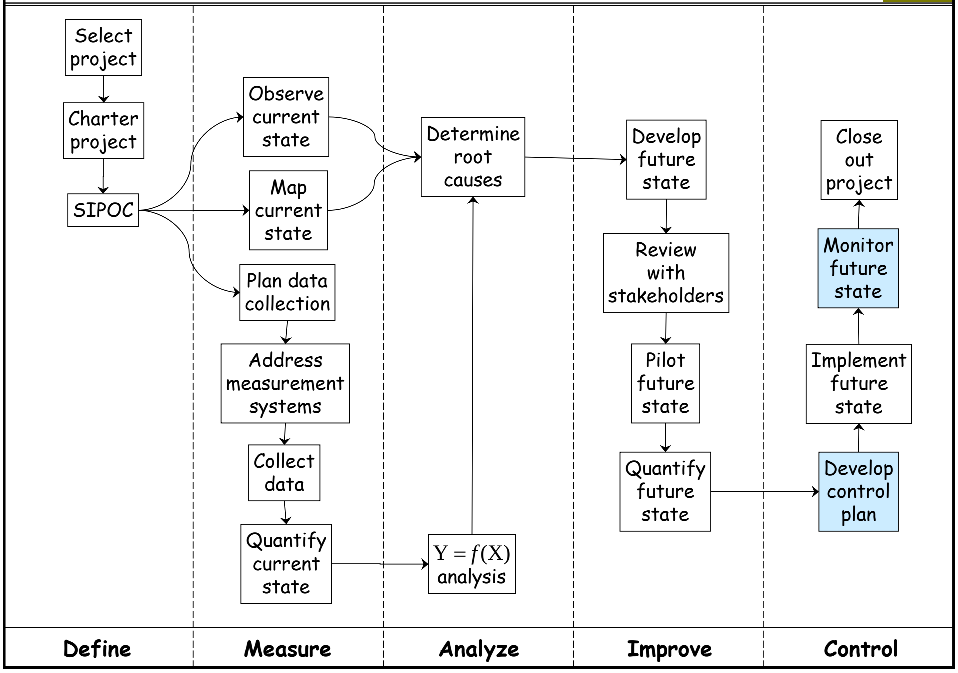
208

Your Instructor will provide instructions

for a Lean simulation.

10 Control Phase of LSS

209



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Topics

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- Control plan
- Statistical monitoring
- Control limits
- Taking action

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Case Study — Tool Development: control plan

211

Process name:	Tool Testing Process
Process owner:	Testing Area Manager
Revision date:	

Process step	Control method	Frequency	Data variable	Meas. system	Metric to monitor	Control limits		Response plan owner	Response plan location
						Lower	Upper		
Determine run conditions	Audit compliance with new procedure requiring special approval to change weight or line speed	Monthly, then Quarterly	Run conditions						
Determine run conditions	Disable weight and line speed controls on test line								
Release to manufacturing	Control chart	Weekly	Number of days in testing	Database	Average	0	8.5	Testing area manager	Doc Control system
Release to manufacturing	Control chart	Weekly	Number of rework cycles	Database	Average	0.4	2.8	Testing area manager	Doc Control system
Dimensional inspection	Install DVT gage and trainer testers to use it	one-time, refresher training							
Dimensional inspection	Periodic gage R&R	Monthly, then Quarterly	Spec dimensions	DVT	% of Tolerance (goal $\leq$30%)			Testing Engineer	

211

Exercise 13: Signatures

212

a) Sign your name five times in the space provided below.

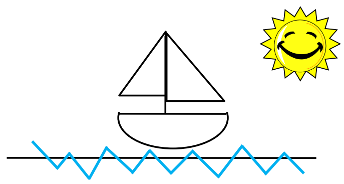
b) Put your pencil or pen into the other hand. Sign your name once in the space provided below.

212

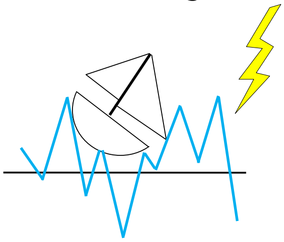
Two kinds of variation

213

Variation due to *common causes*



Variation due to *assignable causes*



Two kinds of variation (cont'd)

214

Common causes	*Assignable causes*
Random variation	Systematic variation
Inherent in the process as currently defined	External factors, mistakes, malfunctions, miscommunications, etc.
Myriad small fluctuations, causes *cannot* be assigned	Relatively few large fluctuations, causes *can* be assigned and removed
Outcomes are predictable within statistical limits	Outcomes are not predictable at all

Control limits

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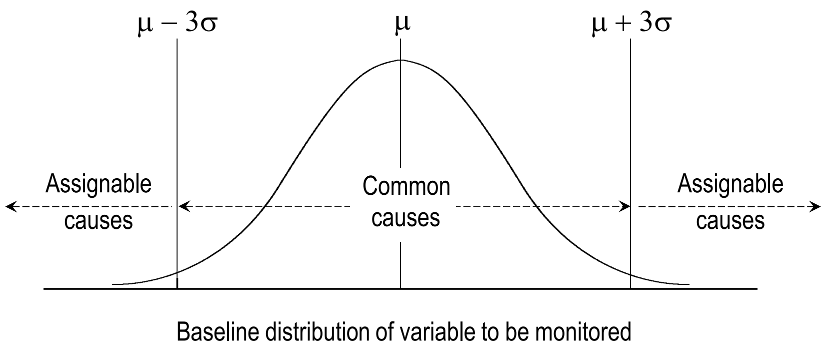
Most often we use *three-sigma limits* to distinguish operationally between assignable causes and common causes



μ = average
σ = standard deviation

Control chart

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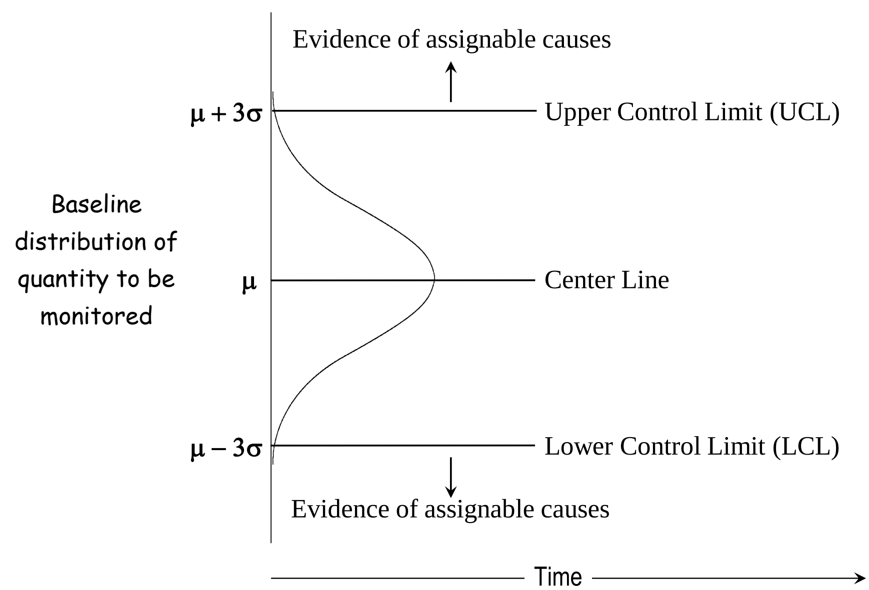
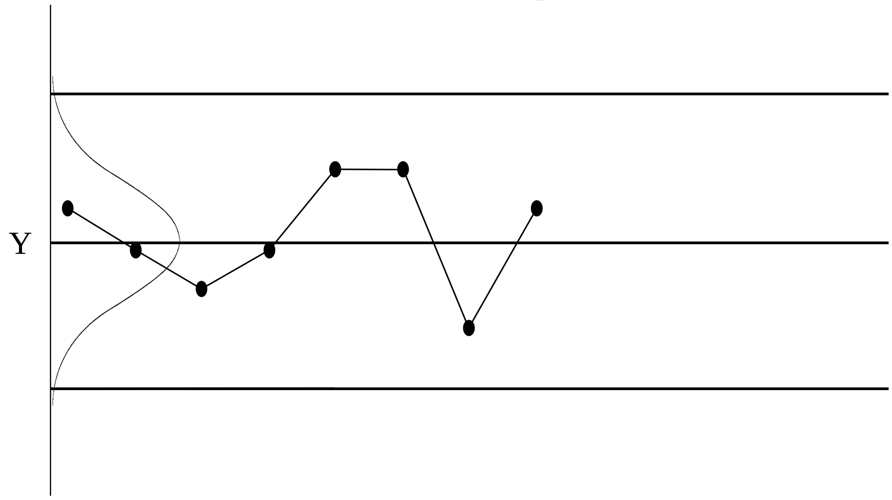


Statistical monitoring

217

Establish expected limits of statistical variation based on the pilot data



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Taking action

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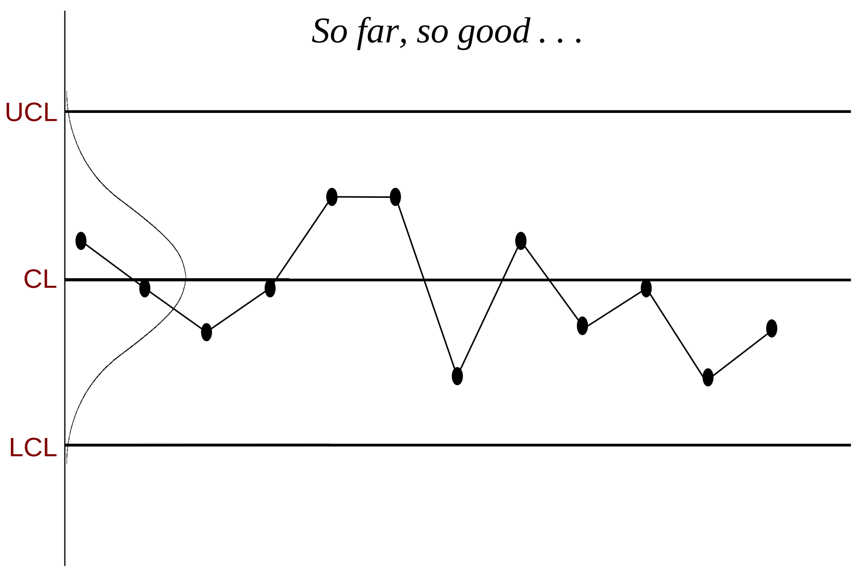
So far, so good . . .



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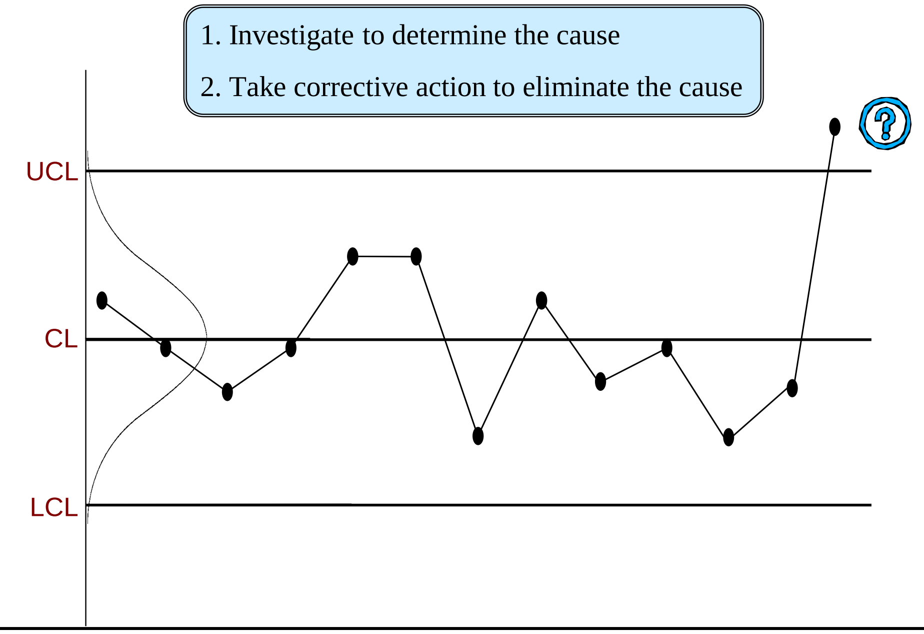
Out-of-control event (OOC)

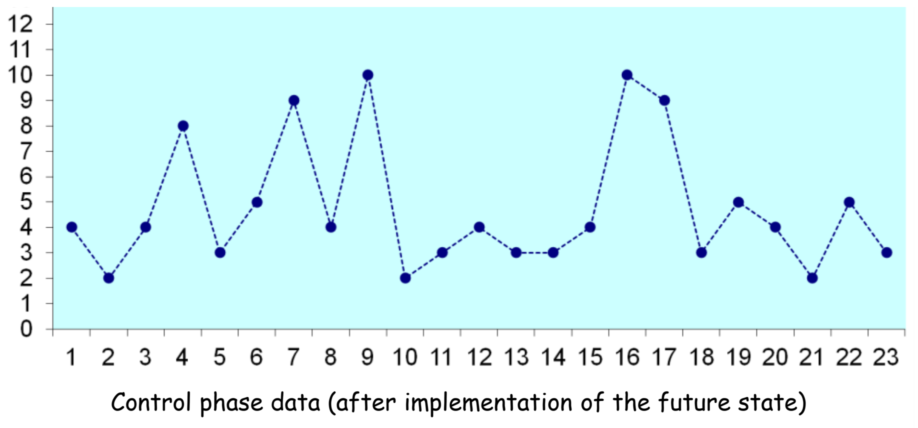
219



Exercise 14: Control limit calculation

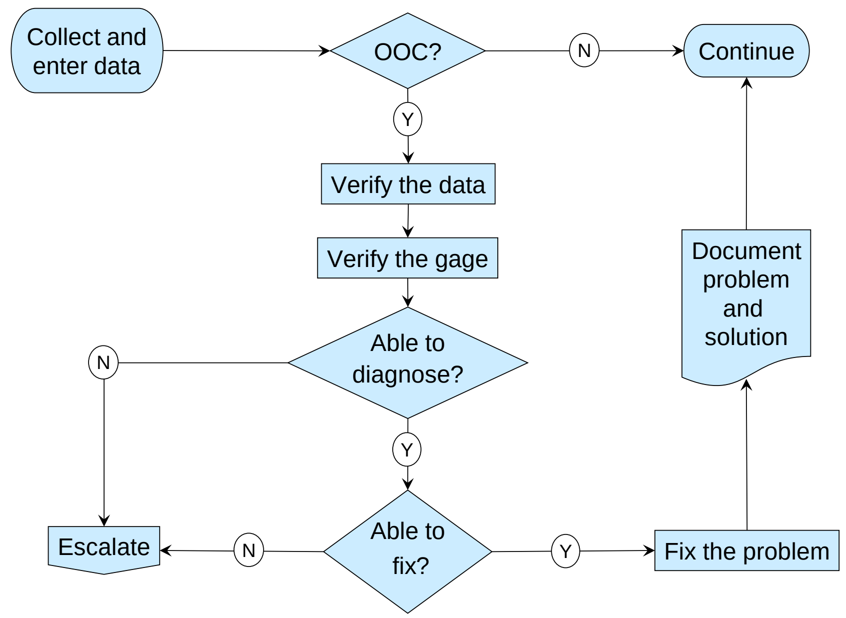
220

- The average value from the future state pilot data was 4.5, and the standard deviation was 1.5
- Calculate the upper control limit, then draw the corresponding horizontal line on the chart
- Circle any data points that represent assignable causes



Response plan “skeleton”

221



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Response plan considerations

222

OOC stands for “out of control.” It means the control chart indicates an assignable cause according to one or more selected tests. A point outside the control limits is one such test. Some other tests will be described later.

The success of statistical monitoring depends on having a documented plan for responding to out-of-control signals. The most successful form of documentation for a response plan is a process map like the one shown here, posted in a place clearly visible to process participants.

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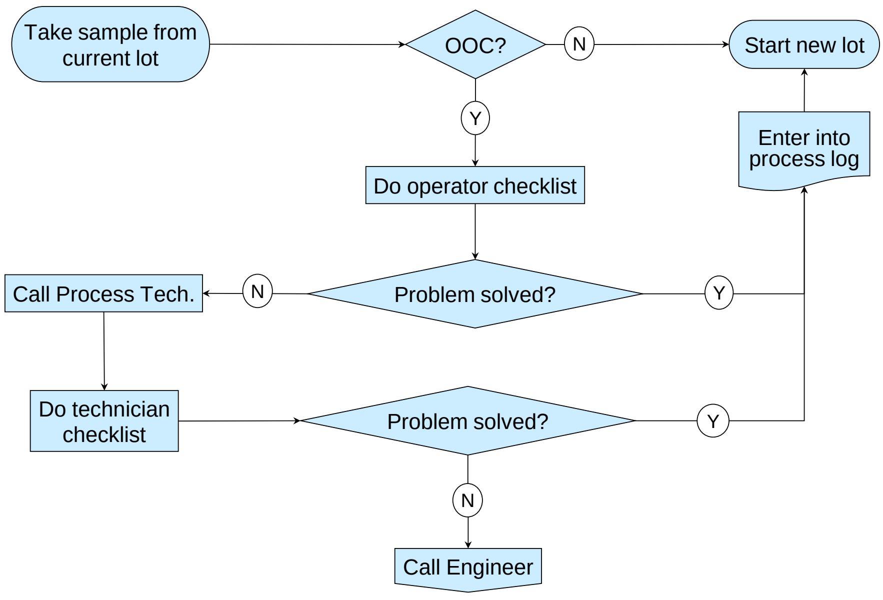
Response plan example



Response plan example (cont'd)

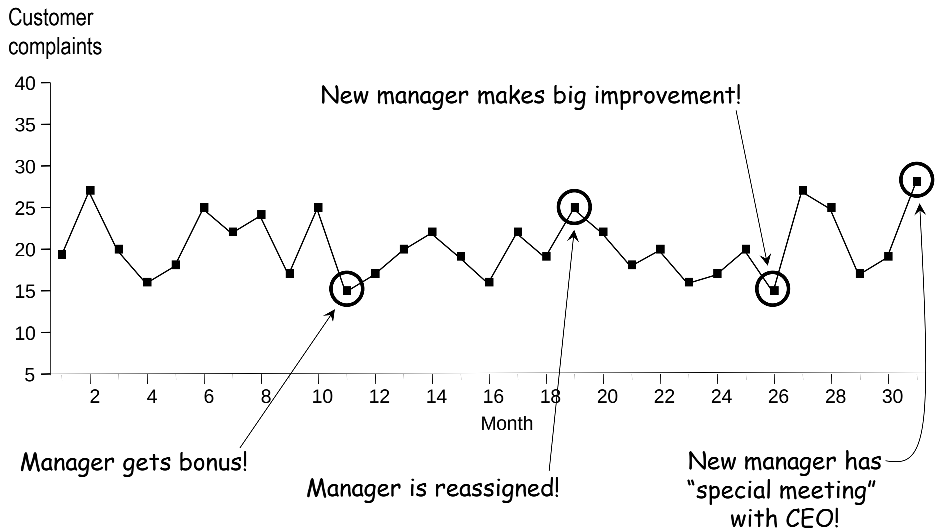
The previous slide is a real example ("sanitized" a little) from a high-volume automated assembly process. It was developed by a team including operators, technicians, engineers and the manufacturing area manager.

Based on experience, they wanted to verify an OOC on the first sample with a second sample from the same lot before going into investigation mode. Note the escalation from Operator to Technician to Engineer.

Once investigation mode was entered, production was halted until the *Start new lot* point in the response plan was reached. This may seem like harsh discipline, but it worked. Within a few months of implementation, previously chronic equipment and process issues were quickly sorted out. As a result, unplanned downtime and use of Engineering support plummeted. Manufacturing productivity increased dramatically, and engineers were able to spend more of their time on development projects.

Over-reacting to data

225

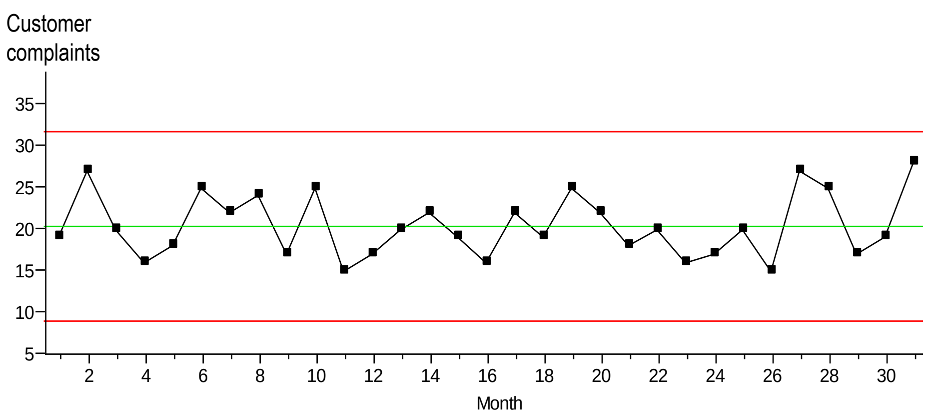


225

Over-reacting (cont'd)

226

There are no assignable causes here!

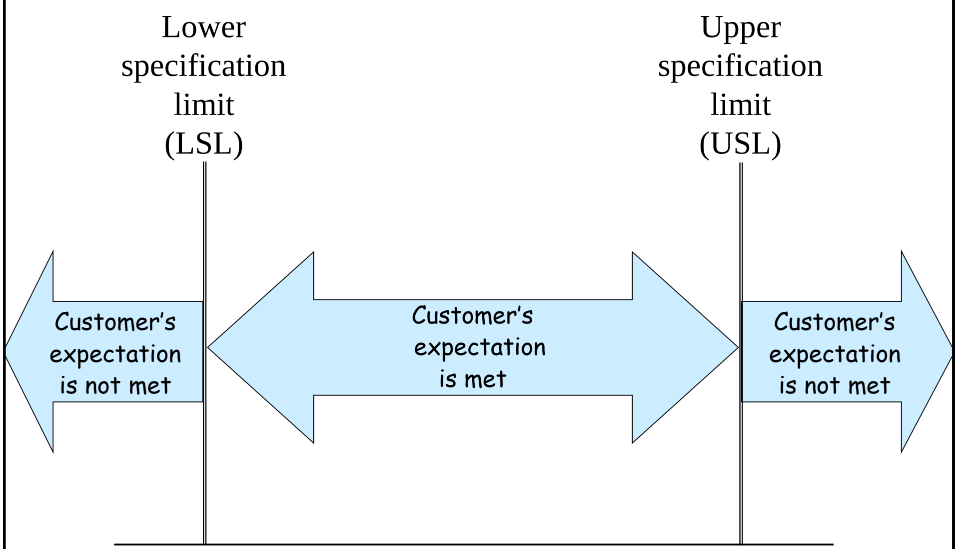


- If there is a problem here, it is the **average** number of complaints
- This problem cannot be solved by reacting to individual data points
- What would be a **rational** approach to solving this problem?

226

What about specification limits?

227



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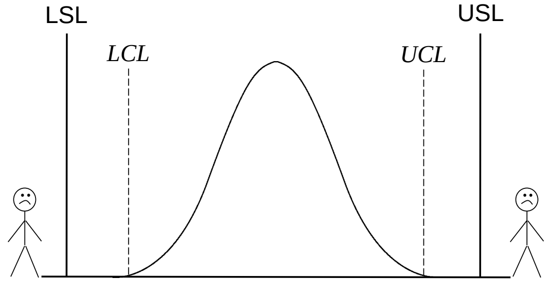
Specification limits (cont'd)

228

Specification limits represent what the customer will and with not accept. Data points outside the spec limits always trigger a disposition process, usually scrap or rework. However, data points outside the spec limits *may or may not* trigger the response plan. It all depends on whether the process in question has good or bad statistical capability.

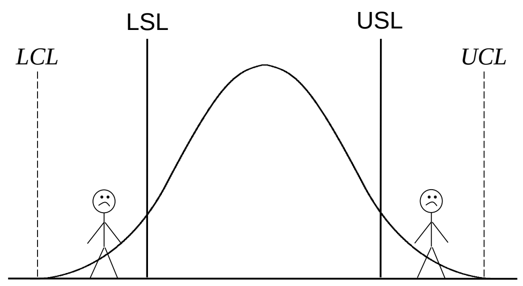
228

The role of process capability



- If a process has good capability, the control limits are inside the spec limits
- Any data point outside the spec limits is automatically an assignable cause, and should trigger the response plan

Process capability (cont'd)



- If a process has poor capability, the control limits are outside the spec limits
- There will be data points outside the spec limits that are not assignable causes
- These points should *not* trigger the response plan

Summary

Thank you for participating

in ETI Group's

Lean Six Sigma Yellow Belt Workshop!

We will "test" our knowledge and share key learnings together.

You will also receive a link to a Course Evaluation.

We appreciate you taking a few minutes of your time to give us constructive feedback.